ILLINOIS
STATE GEOLOGICAL SURVEY

STATE OF ILLINOIS

DEPARTMENT OF REGISTRATION AND EDUCATION

DIVISION OF THE

STATE GEOLOGICAL SURVEY

FRANK W. DeWOLF, Chief

BULLETIN No. 38

YEAR BOOK FOR 1917 AND 1918

ADMINISTRATIVE REPORT

AND

ECONOMIC AND GEOLOGICAL PAPERS

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS

1922

(53005-1M-7-21)

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION

DIVISION OF THE

STATE GEOLOGICAL SURVEY

FRANK W. DeWOLF, *Chief*

LETTER OF TRANSMITTAL

STATE GEOLOGICAL SURVEY DIVISION, JULY 1, 1921

W. H. H. Miller, Chairman, and Members of the Board of Natural Resources and Conservation,

Gentlemen: I submit herewith my administrative report for the fiscal years begun July 1, 1917, and ended June 30, 1919, together with nine other papers of varied character.

It is the duty of the Geological Survey Division of the Department of Registration and Education to investigate and encourage the development and conservation of the mineral resources of the State. This work has two chief phases: first, the systematic surveying and mapping of the entire State in quadrangle or county units, and second, the investigation of such local areas or specific mineral industries as from time to time seem to require attention.

As a contribution toward the systematic mapping of the geology of the State, two quadrangle reports covering parts of Rock Island, Mercer, Fulton, Knox, Warren, and McDonough counties are here published.

Another report of permanent value is the presentation of production statistics for the calendar years 1917 and 1918. This work is carried on in coöperation with the United States Geological Survey.

A large part of the work during the biennium has been devoted to the investigation of oil and gas possibilities. A report of these activities for the period has already been published as Bulletin 40 and only brief mention of that work is given in the administrative report accompanying this volume.

Most of the work of the Survey during the biennium has been specially adapted to the war-time needs of the country and of the State for certain minerals which were either cut off from import or were needed closer to the points of consumption, in order that rail transportation might be relieved. The steps taken to render assistance are outlined at some length in the following administrative report; and the short papers immediately following relate to investigations of fire clays, optical fluorite, pyrite, and low-sulphur coal, all of which were of considerable importance during the war period. The accompanying paper on oil shale is not related to the war work but was planned to meet the many inquiries regarding oil shale possibilities received by the Survey. While it presents little new information, it places in convenient form the material which was scattered in many publications, some of them difficult of access to most readers.

Four of the papers have already appeared as extracts from this bulletin, namely, those on optical fluorite, fire clay, and quadrangle areas, but the others are here published for the first time.

Very respectfully,

F. W. DEWOLF, *Chief*

CONTENTS

ADMINISTRATIVE REPORT FROM JULY 1, 1917 TO JUNE 30, 1919

By F. W. DeWolf, Chief

OUTLINE

TABLES

INTRODUCTION

General Statement

During the biennium beginning July 1, 1917, and ending June 30, 1919, the work of the Geological Survey was chiefly directed to encouraging production of certain war minerals or to other work which had a bearing on war needs of the country and of the State. Certain essential minerals were cut off from import because of ship shortage; others were needed in increasing amounts by war industries; or from new sources near points of consumption, in order to release transportation congestion. The Chief of the Division assisted in creating the War Minerals Committee in Washington which had for its purpose to determine the need for new production and to stimulate coöperation of national, state, and private agencies in an effort to meet the requirements. Later, on leave of absence, the Chief served as Assistant Director of the U. S. Bureau of Mines, giving special attention to the stimulation of war-minerals production and to other matters of importance to the prosecution of the war which were being handled in large volume by the Federal bureau. At the same time he kept in touch with the Survey program which was being ably directed by Mr. Savage as acting chief.

After the armistice, some of the war activities of the Geological Survey were continued in order that results of permanent value might be obtained, but normal work was resumed as rapidly as possible in harmony with the general program of investigating and mapping the geology and mineral resources of the State. Normally the function of the Survey is to assist the mineral industries and the general public by making known the location, depth, general character, and availability of our mineral wealth; and since Illinois ranks third in the value of its mineral products, this work has been of state-wide importance. However, it was largely laid aside, as already stated, during the war period, except in the case of certain lines of investigation which were not only justified but demanded by the prevailing situation.

As explained in a later paragraph, the topographic program of surveying the State in coöperation with the Federal Government was disorganized during the war period, but one quadrangle was surveyed by the State itself under contract with a private firm. Later in the biennium the normal program was resumed.

In the following pages will be found brief descriptions of the organization and personnel of the Survey and of each of the activities carried on during the biennium. The statement of expenditures (Table 2), shows a classification by subjects.

Organization and Personnel

Beginning July 1, 1917, the Civil Administrative Code went into effect and the State Geological Survey became a Division in the Department of Registration and Education. A Board of Natural Resources and Conservation was appointed to collaborate with the Director of the Department, in the determining of policies and of personnel for the scientific Surveys. This Board included the following:

Ex officio members

Francis W. Shepardson, Ph.D., LL.D., Director of Registration and Education, Chairman

Dean Kendric C. Babcock, Ph.D., LL.D., representing the President of the University of Illinois, who resigned on October 30, 1917, in favor of Dean David Kinley, Ph.D.

Appointed members

Thomas C. Chamberlin, Ph.D., Sc.D., LL.D., University of Chicago, representing geology

William Trelease, Sc.D., LL.D., University of Illinois, representing biology

John M. Coulter, Ph.D., University of Chicago, representing forestry

William A. Noyes, Ph.D., LL.D., University of Illinois, representing chemistry

John W. Alvord, C.E., Chicago, representing engineering

The appointment of Doctor Chamberlin to represent geology was fortunate because his service on the Geological Survey Commission had been continuous since 1905. In May, 1919, however, Professor Chamberlin tendered his resignation, and as his successor upon the Board, Professor Rollin D. Salisbury, head of the Department of Geography at the University of Chicago, was chosen.

The Board held several full meetings during the biennium and during the interim between meetings considered and decided problems of the Geological Survey Division through the sub-committee consisting of the Director of the Department, ex officio, the representative of the President of the University of Illinois, ex officio, and Professor Salisbury.

The Survey is informally subdivided into a general office section and three technical sections; geologic, topographic, and mining investigations. The topographic work was not done continuously as in the past in coöperation with the U. S. Geological Survey because of the situation which arose during the war. However, before the close of the biennium normal relations had been re-established. This work was under the general supervision of R. B. Marshall, Chief Geographer of the U. S. Geological Survey, and the immediate direction of William H. Herron, Geographer in Charge of the Central Division.

The work of the Geological section and of the Mining Investigations section was administered by F. W. DeWolf, Chief, the latter work in accordance

with a joint program approved by a representative of the Mining Department of the University of Illinois and the Director of the U. S. Bureau of Mines. The Bureau continued to maintain an office at Urbana as headquarters for mining engineers and chemists engaged in the coöperative work.

Due to war-time uncertainty and the unusual demand for the service of geologists, there was an almost complete change of technical personnel of the Survey during the biennium.

Mr. Nebel, who was in charge of the oil investigations, resigned September, 1918, to accept an attractive position elsewhere. Mr. Coryell, who joined the staff in April, 1918, as geologist engaged on oil investigations, took leave of absence in April, 1919, to resume university studies, and tendered his resignation in June. Mr. Mylius joined the organization in April of 1919 and took up the usual oil investigations, and also the engineering aspects of controlling water at wells. This latter work had been commenced by Mr. Nebel in coöperation with the Bureau of Mines engineers. Other oil work was carried on in the main fields of eastern Illinois by D. J. Fisher and by Marvin Weller.

Several complete geological surveys of quadrangle areas were undertaken. Mr. T. E. Savage did the work on the Jonesboro quadrangle in southern Illinois, assisted by Mr. von Schlicten, and at the same time Mr. Knappen began work on the Dixon quadrangle in northern Illinois. Later in the biennium Marvin Weller was assigned to the survey of the Campbell Hill quadrangle in southwestern Illinois.

In connection with investigations of fire clay, ganister, and silica, undertaken largely because of the war-time shortage, Professors Washburn and Parmelee of the University of Illinois, were appointed as consulting ceramists, and C. R. Schroyer, geologist, was appointed in the spring of 1918 to do the field work. The testing of clay and ganister samples in the laboratory required the employment of several student assistants under the direction of Professor Parmelee.

The investigation of limestone resources was outlined in a preliminary way early in 1919 by Mr. Schroyer, but he took leave of absence in March to resume studies at the University of Chicago and tendered his resignation in June on account of ill health. The work was later undertaken by Mr. Krey, assisted by Mr. Lamar, and late in the biennium Mr. Leighton joined the organization as expert on glacial gravel deposits, but with the understanding that he would give part time to the Geology Department of the University of Illiniois. Mr. Leighton was assisted by Mr. Wingert.

The coal investigations of the Survey were carried on by Mr. Cady until the time of his resignation in June, 1919, for an engagement abroad. Mr. Culver was appointed as part-time geologist to investigate coal problems but with the expectation that he would give half time to the University of Illinois. The work of the Mining Investigations engaged much of Mr. Cady's

time on the study of coal resources, pyrite recovery, and the occurrence of low-sulphur coals suitable for gas manufacture. In addition, William A. Dunkley, gas engineer, was secured in July, 1918, to collaborate with an engineer of the Bureau of Mines on a joint program in coöperation with the Illinois Gas Association. The problems and progress of the work are reviewed in a later paragraph.

In 1917 Mr. Currier was employed to make a study of the ore deposits of Hardin County, after which, in 1918, he undertook oil investigations in western Illinois.

Just before the close of the biennium, it became apparent that the Survey would be given a special appropriation for an investigation of our overflowed lands and their reclamation, and G. W. Pickels of the Civil Engineering Department of the University was secured to undertake this work.

The following list includes the full personnel of the staff for the biennium, with the exception of a few part-time assistants employed for short periods.

GENERAL OFFICE SECTION

F. W. DeWolf, Chief*
Carrie H. Thory, Chief Clerk*
Henry M. DuBois, Asst. Geologist
Nellie Barrett, Editor*
Henrietta Christensen, Geologic Clerk*
Faith Neighbour, Stenographer*
Emma J. Nyberg, Stenographer*
W. B. Walraven, Draftsman (In service)*
Marian Ream, Draftsman
A. L. Rehnquist, Draftsman

GEOLOGIC AND MINING INVESTIGATIONS SECTION

F. W. DeWolf, Geologist*
R. D. Salisbury, Consulting Geologist
U. S. Grant, Consulting Geologist
Harlan H. Barrows, Consulting Geologist
S. W. Parr, Consulting Chemist
Edward Bartow, Consulting Chemist
Stuart Weller, Geologist
T. E. Savage, Geologist
G. H. Cady, Geologist*
Charles Butts, Geologist (U. S. G. S.)
Merle L. Nebel, Geologist*
L. A. Mylius, Geologist*
H. N. Coryell, Geologist*
J. L. Rich, Geologist
J. H. Bretz, Geologist
L. W. Currier, Geologist
J. E. Pogue, Geologist
C. R. Schroyer, Geologist*
Frank Krey, Geologist*

*Employed on full-time basis

GEOLOGIC AND MINING INVESTIGATIONS SECTION—(Concluded)

M. M. Leighton, Geologist
H. E. Culver, Geologist*
C. W. Parmelee, Ceramic Engineer
W. A. Dunkley, Gas Engineer*
G. W. Pickels, Drainage Engineer
H. F. Crooks, Assistant Geologist
S. H. Williston, Assistant Geologist
Marvin Weller, Assistant Geologist
J. E. Lamar, Assistant Geologist
D. J. Fisher, Assistant Geologist
Carl v. Schlicten, Assistant Geologist
M. H. Hunt, Assistant Ceramic Engineer
D. D. Sparks, Levelman
R. Pinheiro, Levelman
Morris Winokur, Levelman
G. F. Moulton, Field Assistant
A. W. Thurston, Field Assistant
R. C. Miessler, Field Assistant
K. W. Hsu, Field Assistant
E. L. Wingert, Field Assistant
Ben Herzberg, Field Assistant
Other short-time assistants in field and office

*Employed on full-time basis.

Coöperation

Mention has already been made of the formal coöperation with the U. S. Geological Survey in the work of making a topographic map of the State. There has also been the usual coöperation in collection of mineral statistics. Mention has been made of the coöperation with the Mining Department of the University of Illinois and with the U. S. Bureau of Mines in work relating to the study of coal resources and the better development of mining practices and of coal utilization. This work has also included the effort to demonstrate methods of shutting off water from oil wells. Besides these instances of formal coöperation, it is a pleasure to mention in addition the availability of the ceramics and chemical laboratories of the University, together with consulting members of the faculty who direct certain routine analytical and testing work on behalf of the Geological Survey. All of these various lines of coöperation are highly appreciated.

GEOLOGICAL AND MINING INVESTIGATIONS SECTIONS

General Stratigraphy and Structure

Stratigraphical studies of the Mississippian formations were continued by Professor Weller in the Golconda and Vienna quadrangles in southern Illinois. General stratigraphy and structure of the formations was investigated in five other quadrangles, comprising a total area of about one thousand square miles. Additional stratigraphic and structural data of significance in relation to our oil fields were collected in western Illinois and in the northern portion of the eastern oil fields.

Coal

The Survey carried on a considerable amount of general investigation of the coal fields, incidental to the mapping of the State, but for the most part special coal studies were undertaken under the Illinois Mining Investigations Coöperative Agreement. This work engages the joint efforts of geologists, mining engineers, and chemists on a program which is adopted for each year.

In the first year of the biennium an investigation of the coal resources, along with other mineral products, was carried on for several unit areas in various parts of the State. The Coulterville quadrangle, lying in Randolph and Perry counties was surveyed by Mr. Cady; the Ottawa and Marseilles quadrangles, lying in La Salle and Grundy counties, were in large part finished by Mr. Cady and Mr. Crooks; the Edgington quadrangle, comprising parts of Rock Island and Mercer counties, by Mr. Savage; the LaHarpe and Good Hope quadrangles, lying in Henderson, Hancock, McDonough, and Warren counties, by Mr. Nebel and assistants; the Campbell Hill quadrangle, lying in Jackson, Randolph, and Perry counties, by Marvin Weller. Of these combined areas about one thousand square miles lie within the Illinois coal fields.

During the second year the coal work of the Survey related largely to difficulties brought about by the war; particularly to the shortage of gas coal and coke for use at Illinois gas plants. Previously, about two million tons of low-sulphur coal had been shipped annually to Illinois and the states adjoining on the west from mines in the eastern states, but rail congestion, the zoning of coal, and other difficulties interfered to an alarming extent with the supply. Since Illinois coal had been used in a small way at a few gas-making plants, it seemed wise to consider its larger use in an effort to relieve the shortage. Incidentally it was thought possible and desirable to develop a permanent market for Illinois coals in gas manufacture. Hence plans were made and a coöperative organization perfected for immediate experiment on a commercial scale. The Governor appointed a special technical committee on this work, including representatives of the Survey, the Engineering Experiment Station of the University of Illinois, the U. S. Bureau of Mines, and the Illinois Gas Association. Under this committee, gas engineers and chemists carried on practical and highly successful experiments, and the results were published and distributed through a representative of the U. S. Fuel Administration. It was found possible to make satisfactory gas from certain grades of Illinois coal and largely to overcome such difficulties as were due to the change from eastern coal. On the whole, certain economies were found to result from this practice, and it is therefore presumed that many plants will continue to use Illinois coal permanently. Mr. Dunkley was engaged as fuel engineer on behalf of the Survey, and carried much of the responsibility.

The publications of this series of studies are listed on a later page in this report. In this connection should be mentioned the report of Mr. Cady, pointing out the location of twenty-two mines in Franklin, Williamson, Perry, and Jackson counties which can produce low-sulphur coal acceptable to the gas industry.

Another geological work of the Mining Investigations included the completion of a report by Mr. Cady on the coal resources of Saline and Gallatin counties, and the conclusion of field work by Mr. Cady on coal resources of the Springfield-Peoria region.

Pyrite

Another investigation closely related to coal studies included a search for pyrite, as a by-product of coal production. Because of war conditions the pyrite ordinarily imported from Spain was cut off. It became increasingly necessary that a larger supply should be produced in the United States for use in the manufacture of sulphuric acid, which, in turn, is necessary for the manufacture of explosives. Consequently, under stimulation from Government agencies, an inventory was made of pyrite, or "sulphur balls," in Illinois coal mines. This work was encouraging from the start because there had been small commercial production for many years from mines in the vicinity of Danville. Mr. Pogue and later Mr. Cady made the investigation and prepared a brief publication which is listed with others on a following page. In general a great quantity of pyrite was found to be available and commercially recoverable, but about the time this investigation was completed it became clear that the production of natural brimstone from Louisiana and Texas would probably supplant pyrite in acid manufacture.

Oil and Gas

The oil investigations of 1917-1918, comprising a large program, have previously been published as Bulletin 40. This volume contains a summary of the production statistics, notes on various scattered localities, and also geological reports with recommendations for new drilling in a number of counties. In western Illinois a survey of Brown County was made in the fall of 1917 by Messrs. Rich and Nebel, Mr. Rich having the northern part of the county and Mr. Nebel the southern part. In addition, Mr. Nebel made a special investigation of the oil structure of the LaHarpe and Good Hope quadrangles, comprising parts of Henderson, Warren, Hancock, and McDonough counties. During the following summer Mr. Coryell prepared a report on Pike County and southeastern Adams County.

In eastern Illinois, Mr. Nebel, assisted by Marvin Weller, and later Mr. Mylius, assisted by Mr. Collingwood and J. H. Griftner, carried on a survey of the old oil fields in Clark and northern Crawford counties. This proved to be of increasing importance because of the commercial discovery of oil in the Trenton in the vicinity of Westfield. It seems likely that the struc-

tural mapping of the region will be of great value in the future development of this deep production.

In coöperation with the U. S. Bureau of Mines the Survey undertook to demonstrate the use of mud fluid and cement for shutting off water in oil wells of the Flat Rock pool in southeastern Crawford County. This work was begun by Mr. Nebel, followed by Mr. Mylius on behalf of the Survey, and by Mr. Tough, followed by Mr. Wagy on behalf of the Bureau of Mines. Mr. Williston of the Survey assisted the party.

Detailed reports on these various investigations, together with full acknowledgments, will be found in Bulletin 40. Suffice it to say that the oil work engaged a large part of the staff, and as shown by Table 2, a substantial portion of the total appropriation.

Geological Surveys of Quadrangles

Only a little quadrangle survey work was done in coöperation with the United States Geological Survey, and this was in the Coulterville quadrangle, by Mr. Cady. This area comprises 200 square miles lying in Randolph, Jackson, and Perry counties. Independent of Federal work, the State carried on surveys of the Edgington quadrangle in Rock Island and Mercer counties, began work on the Ottawa and Marseilles quadrangles in La Salle and Grundy counties, completed the survey of the LaHarpe and Good Hope quadrangles in Henderson, Hancock, McDonough, and Warren counties, finished the Golconda quadrangle and about one-half of the Vienna quadrangle in southern Illinois, and published a special report on the Kings quadrangle in the vicinity of Camp Grant. The Campbell Hill survey in southwestern Illinois was finished by Marvin Weller. Mr. Butts of the U. S. Geological Survey finished work on the Shawneetown and Equality quadrangles in southern Illinois, under an arrangement by which the Federal Government paid his salary and the State shared the expenses.

Clay

During normal times a considerable tonnage of high-grade clay for the manufacture of graphite crucibles, glass pots, retorts, etc., is imported from England and from Germany, but on account of the war situation these imports were essentially cut off. Under encouragement from Federal agencies, the State Survey began a search for high-grade clays which might be used in the emergency. Mr. C. R. Schroyer was appointed as field geologist and C. W. Parmelee and E. W. Washburn, head of the Ceramics Department of the University of Illinois, were appointed consulting ceramists. A program of field work and laboratory tests was arranged and carried to a successful conclusion, more than one hundred samples of high-grade clays having been collected. Deposits in Union County were found to be suitable for use in making glass pots, linings for crucibles and retorts, and for enameled iron. Other studies of ganister found in Union and Alexander

counties were undertaken because this material promised to have value for the manufacture of silica brick which is used for coke-oven linings and similar purposes. Certain tests of this material were made by the U. S. Bureau of Standards and others are to be made in the University laboratories under the direction of Mr. Parmelee.

Investigation of Highway Materials

Late in the biennium it became desirable to undertake a search for sites for additional limestone quarries and gravel pits which might be opened up to furnish material for the road program which the State is undertaking. Conferences were held with representatives of the State Highway Division and the Director of the Department of Public Works, looking to a systematic examination of the possibilities in all parts of the State and the collection of samples which would be tested by the Highway Division at Springfield. Mr. C. R. Schroyer and assistants began the work of preparing loose-leaf forms for the recording of limestone observations and plans were made to obtain a specialist on glacial geology to undertake study of gravel deposits. It was assumed that a special appropriation for the execution of this work might become available July 1, and all plans were made to push the investigation rapidly. Since the State program calls for approximately 1,000 miles of road per year for the five-year period immediately following the war, and since much of the stone and gravel in our State is shipped in from Wisconsin and Indiana, it seems important to investigate the possibilities of producing satisfactory Illinois materials so as to practice all possible economy. Furthermore, the production of additional limestone would yield an important quantity of lime-rock dust for agricultural use.

Mineral Statistics

The Survey has continued to coöperate with the U. S. Geological Survey in the collection of mineral statistics and the results for the years under consideration are given on a later page in a chapter by Miss Barrett.

Bureau of Information

The Survey maintains a bureau of information for the convenience of inquirers about mineral resources of Illinois. Requests are received in great numbers, both from inside and outside the State. When possible, a bulletin containing the desired information is mailed. Frequently, however, it is necessary to make special study and to reply by letter at some length. Many requests for the identification of minerals are received and answered promptly; others for chemical analysis of specimens are, for the most part, necessarily refused. It has been found that the collection of a representative sample of a material and the investigation of its favorable occurrence for development are quite as essential and require expert advice, just as does chemical analysis. As a rule, therefore, unless a representative of the Sur-

vey investigates and samples a mineral deposit, an analysis at public expense is not justified, particularly because otherwise Survey funds would be seriously depleted by work which frequently is of no permanent value. Preliminary examinations and opinions as to probable value of minerals are always cheerfully given.

Topographic Section

The accompanying table indicates the progress of topographic mapping for each of the two years comprising the biennium.

It seemed desirable to suspend topographic surveys in Illinois during the year beginning July, 1917, partly because they had little bearing on the war necessities of the State, and because Federal employes were largely engaged in active war service abroad or at home, and were not available. However, in connection with the training at Camp Grant, the War Department requested the completion of four quadrangles in that vicinity comprising about 850 miles, and these quadrangles, known as the Rockford, Kings, Belvidere, and Kirkland, were surveyed in coöperation, although most of the cost was borne by Federal agencies.

In connection with Survey investigations of deposits of fire clay and ganister in Union and Alexander counties, it became desirable as a war-time undertaking to have a topographic map of the Jonesboro quadrangle, and to determine accurately the extent and mode of occurrence of these deposits. Consequently a contract was entered into with the Edmund T. Perkins Engineering Company, which company finished successfully the topographic map of this area. Later, after the close of the war, coöperation with the Federal Government was resumed on a small scale, and the survey of the Vermont quadrangle, in Schuyler, Fulton, and McDonough counties, was completed, and about one-half of the work for the Dongola quadrangle was finished. This latter sheet occupies parts of Union, Pulaski, and Johnson counties. In preparation for the following year, levels and control lines were run for the Grays Lake, Barrington, Elgin, McHenry, and Highwood quadrangles, lying partly in McHenry, Lake, Kane, and Cook counties.

An explanation of the progress of the work may best be given in the words of the Director of the U. S. Geological Survey from whose reports for the two years under consideration the following summaries are quoted:

"The Governor of Illinois alloted $7,000 for the continuation of coöperative topographic surveys, and the United States Geological Survey allotted an equal amount, the amount necessary to complete the surveys being paid from Federal funds. The survey of the Kings and Kirkland quadrangles, in Ogle, Winnebago, Dekalb, and Boone counties was completed by J. G. Staack, R. H. Reineck, S. T. Penick, T. F. Slaughter, J. A. Duck, C. C. Gardner, A. L. Opdycke, C. C. Holder, and J. B. Leavitt, the total area mapped being 442 square miles, for publication on the scale of 1:62,500, with a contour interval of 20 feet. For the control of these quadrangles Fred Crisp ran 132 miles of primary traverse and set 12 permanent marks; S. L. Parker. C. C. Holder, and F. A. Danforth ran 80 miles of primary levels, and established 22 per-

TABLE 1.—*Progress of field work by the topographic section*

Quadrangles	Counties	Publication scale	Area mapped	Levels		Traverse		
				Primary	Perm. B. M's.	Primary	Perm. marks	Secondary
July 1, 1917 to June 30, 1918								
			Sq. mi.	*Miles*		*Miles*		*Miles*
Rockford	Winnebago	1:62,500	192	82	12	43	7	20
Kings	Winnebago, Ogle	1:62,500	221	80	22	66	6	465
Belvidere	Winnebago, Boone	1:62,500	215	75	18	66	5	450
Kirkland	Boone, Ogle, DeKalb	1:62,500	221	24	5	66	6	222
	Totals	....	849	261	57	241	24	1,157
July 1, 1918 to June 30, 1919								
Vermont	Schuyler, Fulton, McDonough	1:62,500	63	44	15	...	...	425
Dongola	Union, Pulaski, Johnson	1:62,500	49	38	10	...	...	269
Grays Lake	McHenry, Lake	....	...	30	8	33	4	...
Barrington	McHenry, Lake, Kane, Cook	....	...	...	...	42	3	...
Elgin	McHenry, Kane	....	...	...	...	17	1	...
McHenry	McHenry	....	...	...	...	12	...	...
Highwood	Lake, Cook	....	...	...	...	20	1	...
	Totals	....	112	112	33	124	9	694

manent bench marks in the Kings quadrangle; and C. C. Gardner and H. S. Senseney ran 24 miles of primary levels and established five permanent marks in the Kirkland quadrangle.

"The survey of the Belvidere and Rockford quadrangles, mainly in Boone and Winnebago counties, was completed, the total area mapped being 416 square miles, for publication on a scale of 1:62,500, with a contour interval of 20 feet. Of this area nine square miles is in Wisconsin. For the control of these areas Fred Crisp ran 109 miles of primary traverse and set 12 permanent marks, all in Illinois. For the control of the Rockford quadrangle C. H. Semper ran 82 miles of primary levels and established 12 permanent bench marks, and for the control of the Belvidere quadrangle C. H. Semper, H. S. Senseney, and S. L. Parker ran 75 miles of primary levels and established 18 permanent marks.

"In the spring of 1919 the Department of Registration and Education allotted $7,000 for coöperative topographic mapping in Illinois, with the understanding that an equal amount would be expended by the United States Geological Survey when Federal funds became available. The survey of the Dongola and Vermont quadrangles, in Fulton, McDonough, Schuyler, Union, Johnson, and Pulaski counties, was begun by C. C. Holder, W. K. McKinley, and J. A. Duck, the total area surveyed being 112 square miles, for publication on the scale of 1:62,500, with a contour interval of 20 feet. For the control of these areas S. L. Parker and Crawford Dickey ran 112 miles of primary levels and established 33 permanent bench marks, and F. J. McMaugh ran 124 miles of primary traverse and set nine bench marks."

More rapid progress of topographic mapping throughout the country was emphatically recommended by a conference of engineering societies held at Chicago. This conference consisted of one delegate from each of approximately seventy-five engineering societies in various parts of the country, whose total membership is 200,000 engineers. It seemed likely that the appropriation of the U. S. Geological Survey would be increased $150,000 for topographic work during the coming year, and that its expenditures would continue to be made chiefly in those states which offered like amounts for coöperative work. The Board, therefore, joined in the recommendation that the Illinois Legislature appropriate $20,000 per year instead of $10,000 per year, as carried formerly in the budget. This seemed fully justified because according to estimates in other states, the entire cost of the completion of the Illinois map would be spent in road surveys which would not otherwise be made if the complete topographic map existed. Money expended therefore on topographic surveys is a timely investment which prevents duplicate surveys. The Chief Highway Engineer was invited to indicate parts of the State in which he especially desired topographic surveys so that these might be available to serve highway as well as geological needs.

PUBLICATIONS

Reports and Maps

On account of the war situation the publication of reports of a merely scientific character was practically suspended, and special attention was given to those bulletins and maps which had a bearing on the investigations of mineral resources of which the country stood greatly in need. Near the

close of the biennium, when the war was over, ordinary publication of reports and maps was resumed. The following tabulation will indicate the publications of the biennial period:

Extract from Bulletin 38: Optical Fluorite in Southern Illinois

Coal Mining Investigations Bulletin 20: Carbonization of Illinois Coals in Inclined Gas Retorts

Bulletin 39: The Environment of Camp Grant

Coal Mining Investigations Bulletin 21: The Manufacture of Retort Coal-gas in the Central States Using Low-sulphur Coal from Illinois, Indiana, and Western Kentucky

Coal Mining Investigations Bulletin 22: Water-gas Manufacture with Central District Bituminous Coals as Generator Fuel

Coal Mining Investigations Bulletin 23: Mines Producing Low-sulphur Coal in the Central District

Coal Mining Investigations Bulletin 24: Water-gas Operating Methods with Central District Bituminous Coals as Generator Fuel, A Summary of Experiments on a Commercial Scale

Geological Map of Illinois (New edition)

Coal Mine Map of Illinois (Revised), accompanied by Directory of Operators

At the close of the biennium, the following publications were in press:

Coal Mining Investigations Bulletin 19: Coal Resources of District V

Bulletin 37: Geology and Mineral Resources of the Hennepin and La Salle Quadrangles

Base Map of Illinois (Revised edition)

Topographic Maps of McDonough and Randolph counties

The distribution of these reports so as to prevent waste, and yet make them most widely available, has been in itself a considerable task. It is thought that the interests of all concerned would be best met if 500 copies of each report were reserved for sale at the cost of printing, the receipts from the sales being turned into the State treasury. This makes it possible for libraries to complete their sets and for persons having real need for any of the volumes to obtain the earlier ones at small cost. The remainder of the edition is distributed by the Survey and the Secretary of State to institutions and individuals making application for them, or is exchanged with other Surveys or publishing organizations.

Any of the published reports will be sent upon receipt of the amount noted. Money orders, drafts, and checks should be made payable to F. W. DeWolf, Chief.

EXPENDITURES

The total expenditures July 1, 1917, to June 30, 1919, are shown in the following table:

TABLE 2.—*Total expenditures July 1, 1917 to June 30, 1919*

General appropriation—(50th General Assembly)		
Balance on hand July 1, 1917	$1,609.28	
Appropriation July 1, 1917 (Biennium)	88,044.00	
Total available	....	$89,653.28
Expenditures July 1, 1917 to June 30, 1919—		
Salary and expenses of administration	12,058.26	
Clerical help and general office expenses	15,010.94	
Equipment (field and office)	4,282.22	
Postage	1,375.00	
Oil investigations	11,690.45	
Coal investigations (resources)	2,533.59	
Cooperative geological surveys	488.28	
General stratigraphic studies	285.35	
Clay resources investigations	4,016.63	
Geological surveys (quadrangles)	9,861.89	
Structural geology	219.00	
Educational series	1,986.90	
Statistics	598.08	
Glacial geology	12.06	
Highway materials investigations	1,202.93	
Gas investigations (coal and water gas)	3,992.07	
Pyrite recovery	1,279.10	
Miscellaneous	318.08	
Topographic surveys	12,813.31	
Printing, binding, and engraving	2,100.17	86,124.31
Balance available July 1, 1919	....	$ 3,528.97
Appropriation for engraving and lithographing maps and illustrations—(49th General Assembly)		
Balance on hand July 1, 1917	....	$ 2,398.65
Expended July 1, 1917 to June 30, 1919	....	2,398.65
Balance available July 1, 1919	....	....

An expenditure of approximately $11,000 during the biennium was made from funds of the Department of Registration and Education for publication of reports and maps of the Geological Survey Division.

MINERAL RESOURCES IN ILLINOIS IN 1917 AND 1918

By N. O. Barrett

OUTLINE

OUTLINE—Continued

ILLUSTRATIONS

TABLES

TABLES—Concluded

INTRODUCTION

Purpose and Acknowledgments

In addition to the material customarily comprising the statistical report for the yearbook, this report purposes to include brief notes covering the beginnings and the history of the development of each mineral industry of Illinois. The occasion which prompts such an historical summary of the growth of the State's mineral industries is the Illinois centennial; the close of the first hundred years of statehood in 1918 seems a logical time at which to review the progress that has been made.

Most of the statistics have been taken from compilations made and in many cases published by the United States Geological Survey in its annual reports on "Mineral Resources of the United States," but other sources, such as the Census publications and various State reports were also consulted.

Of recent years, the mineral statistics for Illinois have been collected by the U. S. Geological Survey and the Illinois State Geological Survey in coöperation, rather than by the Federal Survey alone. This custom commends itself to continuance, partly because it gives the State Survey earlier and easier access to the detailed statistics than would otherwise be possible.

Importance of the Mineral Industries

An idea of the relative importance of the mineral industries of the State as compared with agriculture may be gained from Table 3. In spite of the considerable variation from year to year in the percentage ratios of

Table 3.—*Comparison of values of total mineral production in Illinois with those of total agricultural products, 1905-1918*

Year	Mineral production	Agricultural production	Ratio of values of mineral to agricultural production
			Per cent
1905	$ 68,025,560	$272,794,107	24.9
1906	72,723,572	253,409,404	28.7
1907	93,539,464	280,666,020	33.3
1908	92,765,688	276,614,637	33.5
1909	98,840,729	322,144,944	30.7
1910	98,891,759	297,976,709	32.2
1911	106,275,115	311,525,706	34.1
1912	123,068,867	285,249,557	43.2
1913	131,825,221	288,613,140	45.9
1914	117,145,108	289,781,140	40.4
1915	114,704,587	486,561,355	23.5
1916	146,780,236	496,178,000	29.6
1917	238,186,690	842,042,000	28.3
1918	271,244,365	879,679,000	30.8

the values of mineral and agricultural production, it is apparent that commonly mineral production has roughly one-third the value of crops produced.

Evidence of the magnitude of Illinois' mineral wealth is to be found in the fact that in 1918 the State ranked sixth in the United States in petroleum production; fifth in limestone; fourth in clay products; third in brick and tile, in coal, and in sand and gravel; and leader in the fluorspar, glass sand, and tripoli industries. And further evidence is had in the statement that in total value of mineral production it was surpassed in 1917 by only two, and in 1918 by only three other states (fig. 1).

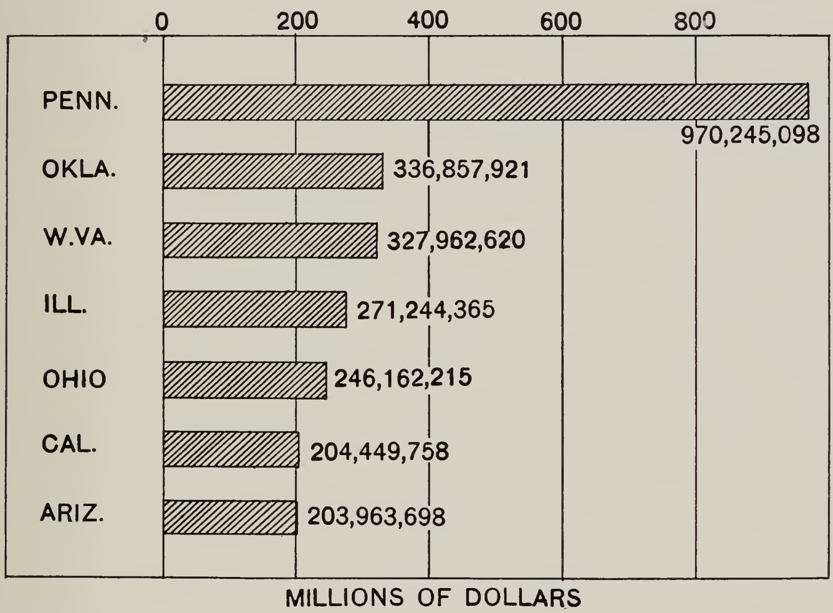


Fig. 1. Rank of Illinois in total value of mineral production, 1918.

Equally impressive is the diversity of mineral resources for the closing year of the State's first century, as shown by the headings in Table 4. Although statistics for the year 1818 are not available, it is certain that a similar list for that year could have been not even a fourth as long. A few barge loads of coal, a goodly quantity of salt, several thousand tons of lead, probably a small cordage of stone, and perhaps a still smaller amount of lime—the combined value and tonnage of the 1818 products could represent only a negligible fraction of present-day values and quantities.

Table 4.—*Output and value of mineral*

Year	COAL								
	Mines			Mines of Specified Tonnage					Tonnage
	Total No.	Shipping	Local	Less than 1,000 Tons	1,000 Tons to 50,000 Tons	50,000 Tons to 100,000 Tons	100.000 Tons to 200,000 Tons	More than 200.000 Tons	Total
1	2	3	4	5	6	7	8	9	10
		Per cent	*Per cent*						*Short tons*
1883........	639	....	....	209	366	39	10	15	12,123,456
1884........	741	....	....	262	421	38	16	4	12,208,075
1885........	778	....	....	286	433	40	13	6	11,834,459
1886........	787	....	....	316	415	44	11	3	11,175,241
1887........	801	....	....	320	419	42	18	2	12,423,066
1888........	822	....	....	327	423	47	20	5	14,328,181
1889........	854	....	....	321	455	55	20	3	12,104,272
1890........	936	....	....	398	456	54	24	4	15,292,420
1891........	918	....	....	402	421	52	37	6	15,660,698
1892........	839	*a*	*a*	332	390	65	46	6	17,862,276
1893........	788	39	61	282	372	75	47	12	19,949,564
1894........	836	38	62	312	413	61	44	6	17,113,576
1895........	855	37	63	319	421	61	45	9	17,735,864
1896........	862	37	63	330	408	63	45	16	19,786,626
1897........	853	36	64	346	370	79	41	17	20,072,758
1898........	881	37	63	351	395	86	42	7	18,599,299
1899........	889	36	64	346	384	77	57	25	24,439,019
1900........	920	35	65	340	418	70	65	27	25,767,981
1901........	915	36	64	313	432	79	58	33	27,331,552
1902........	915	36	64	314	415	76	72	38	32,939,373
1903........	933	38	62	313	413	75	87	45	36,957,104
1904........	932	41	59	301	415	72	98	46	36,475,060
1905........	990	40	60	321	446	83	88	52	38,434,363
1906........	1,018	41	59	336	449	89	97	47	41,480,104
1907........	933	44	56	260	407	91	95	80	51,317,416
1908........	922	44	56	248	402	98	92	82	47,659,690
1909........	886	43	57	270	373	66	90	87	50,904,990
1910........	881	44	56	261	364	87	94	75	45,900,246
1911........	845	46	54	235	351	82	101	76	53,679,118
1912........	879	43	57	266	347	70	91	105	59,885,226
1913........	840	44	56	239	339	66	82	114	61,618,744
1914........	796	43	57	236	298	64	95	103	57,589,197
1915........	779	36	64	268	286	56	65	104	58,829,576
1916........	803	35	65	304	280	48	60	111	66.195,336
1917........	810	40	60	226	283	52	70	139	86,199,387
1918........	967	38	62	334	339	59	69	166	89.291,105

a Statistics not available for this and earlier years.

products in Illinois, 1883 to 1918

COAL—Continued									
Tonnage		Total Value	Men Employed				Machine Mining		Year
Shipping Mines	Local Mines		Total Number	Shipping Mines	Local Mines	Tonnage per Man	No. of Mines	Tonnage by Machines	
11	12	13	14	15	16	17	18	19	20
Per cent	*Per cent*			*Per cent*	*Per cent*			*Per cent*	
....	....	*a*	23,939	....	....	506	....	....	1883
....	....	$13,164,976	25,575	....	....	438	....	....	1884
....	....	11,456,493	25,946	....	....	456	....	....	1885
....	....	10,263,543	25,846	....	....	432	....	....	1886
....	....	11,152,596	26,804	....	....	463	....	....	1887
....	....	13,309,030	29,410	....	....	481	....	....	1888
....	....	12,496,805	30,076	....	....	466	....	....	1889
....	....	12,883,548	28,574	....	....	535	....	....	1890
....	....	13,069,090	32,951	....	....	475	....	....	1891
a	*a*	15,158,430	33,632	*a*	*a*	531	....	....	1892
97	3	17,827,595	35,390	81	19	564	....	....	1893
94	6	15,282,111	38,477	81	19	445	....	....	1894
93	7	14,239,157	38,630	81	19	459	....	....	1895
96	4	15,809,736	37,057	76	24	534	....	....	1896
97	3	14 472,529	33,788	93	7	594	....	....	1897
95	5	14,567,598	35,026	92	8	531	....	....	1898
96	4	20,744,553	36,991	93	7	634	*a*	*a*	1899
96	4	26,927.185	39,384	92	8	639	67	22	1900
95	4	28,163,937	44,143	93	7	603	63	22	1901
96	4	33,945,910	46,005	93	7	653	64	22	1902
96	4	43,196,809	49,814	94	6	702	68	22	1903
96	4	39,941,993	54,774	94	6	677	67	19	1904
97	3	40,577,592	59,230	94	6	628	76	22	1905
97	3	44,763,062	62,283	94	6	615	85	25	1906
97	3	54,687,382	66,714	95	5	717	101	33	1907
97	3	49,978,247	70,841	95	5	696	105	31	1908
98	2	53,522,014	72,733	96	4	676	107	33	1909
97	3	52,405,897	74,634	96	4	653	114	38	1910
97	3	59,519,478	77,410	96	4	648	126	40	1911
98	2	70,294,338	79,411	96	4	724	139	44	1912
98	2	70,313,605	79,497	97	3	778	140	49	1913
98	2	64,693,529	80,035	97	3	758	141	52	1914
98	2	64,622,471	75,607	96	4	762	131	59	1915
98	2	82,457,954	75,919	96	4	839	139	62	1916
98	2	162,281,822	80,893	96	4	976	151	60	1917
98	2	206,860,291	91,372	96	4	985	174	53	1918

TABLE 4.—*Output and value of mineral*

Year	Coke		Oil and Gas		
			Petroleum		Natural Gas
	Quantity	Value	Quantity	Value	Value
21	22	23	24	25	26
	Short Tons		*Barrels*		
1883	13,400	$ 28,200	....	....	....
1884	13,095	25,639	....	....	....
1885	10,350	27,798	....	....	$ 1,200
1886	8,103	21,487	....	....	4,000
1887	9,108	19,594	....	....	6,000
1888	7,410	21,038	....	....	....
1889	11,583	29,764	1,460	$ 4,906	10,615
1890	5,000	11,250	900	3,000	6,000
1891	5,200	11,700	675	2,363	6,000
1892	3,170	7,133	521	1,823	12,988
1893	2,200	4,400	400	1,400	14,000
1894	2,200	4,400	300	1,800	15,000
1895	2,250	4,500	200	1,200	7,500
1896	2,600	5,200	250	1,250	6,375
1897	1,549	2,895	500	2,000	5,000
1898	2,325	4,686	360	1,800	2,498
1899	2,370	5,565	360	1,800	2,067
1900	*b*	*b*	250	1,500	1,700
1901	*b*	*b*	250	1,250	1,825
1902	*b*	*b*	200	1,000	1,844
1903	*b*	*b*	0	0	3,310
1904	4,439	9,633	0	0	4,745
1905	*c*10,307	27,681	181,084	116,561	7,223
1906	268,693	1,205,462	4,937,050	3,274,818	87,211
1907	372,697	1,737,464	24,281,973	16,432,947	143,577
1908	362,182	1,538,952	33,686,238	22,649,561	446,077
1909	1,276,956	5,361,510	30,898,339	19,788,864	644,401
1910	1,514,504	6,712,550	33,143,362	19,669,383	613,642
1911	1,610,212	6,390,251	31,317,038	19,734,339	687,726
1912	1,764,944	8,069,903	28,601,308	24,332,605	616,467
1913	*d*1,859,553	8,593,581	23,893,899	30,971,910	574,015
1914	1,425,168	5,858,700	21,919,749	25,426,179	437,275
1915	1,686,998	7,016,635	19,041,695	18,655,850	350,371
1916	2,320,400	10,619,066	17,714,235	29,237,168	396,357
1917	1,030,706	6,806,930	15,776,860	31,358,069	479,072
1918	2,285,610	18,625,436	13,365,974	31,230,000	620,949

a Statistics not available for this and earlier years.
b Concealed. Less than three producers.
c First year coke was produced in by-product ovens in Illinois.
d Last of the beehive ovens in Illinois permanently dismantled.

products in Illinois, 1883 to 1918—Continued

Clay Products							Year
Number of Firms	Total Value	Common Brick		Drain Tile	Pottery		
		Quantity	Value	Value	Value		
27	28	29	30	31	32		33
		Thousands					
....	....	....	....	....	....		1883
....	....	....	....	....	....		1884
....	....	....	....	....	....		1885
....	....	....	....	....	....		1886
....	....	....	....	....	....		1887
....	....	....	....	....	....		1888
....	....	....	....	....	....		1889
....	....	....	....	....	....		1890
....	....	....	....	....	....		1891
....	....	....	....	....	....		1892
a	*a*	*a*	*a*	*a*	....		1893
697	$ 8,474,360	825,845	$ 4,495,613	$ 1,418,572	....		1894
678	7,619,884	717,079	3,786,747	1,028,581	*a*		1895
566	5,938,247	586,506	2,831,752	517,684	$ 421,482		1896
570	5,498,574	516,263	2,376,498	531,993	618,900		1897
616	6,866,715	573,450	3,205,674	823,847	637,537		1898
643	7,259,825	664,684	3,231,332	1,026,192	763,557		1899
569	7,708,859	685,161	3,981,577	734,249	776,773		1900
550	9,642,490	930,561	5,188,654	694,588	682,449		1901
515	9,881,840	1,023,681	5,131,621	693,783	694,414		1902
502	11,190,797	1,015,541	5,388,589	892,807	899,733		1903
492	10,777,447	999,310	5,167,165	1,002,463	829,696		1904
469	12,361,786	1,125,024	6,259,232	1,051,852	943,007		1905
466	12,634,181	1,195,210	5,719,906	1,052,588	982,903		1906
417	13,220,489	1,494,807	6,499,777	1,031,192	1,004,166		1907
400	11,559,114	1,119,224	4,834,652	1,421,878	806,954		1908
379	14,344,453	1,257,025	5,927,054	1,613,593	838,555		1909
346	15,176,161	1,196,526	6,896,836	1,613,698	844,747		1910
330	14,333,011	1,074,486	6,126,911	1,372,049	979,811		1911
301	15,210,990	1,210,499	6,437,331	1,189,910	931,951		1912
281	15,195,874	1,155,480	6,445,821	1,225,190	915,263		1913
263	13,318,953	941,343	4,898,698	1,041,927	780,579		1914
254	14,791,938	1,066,057	6,870,990	991,709	948,892		1915
225	17,633,351	1,182,473	6,738,152	1,200,465	1,125,506		1916
207	17,190,753	738,963	5,138,822	1,314,006	1,571,262		1917
168	12,459,777	365,958	3,218,758	1,077,861	1,769,735		1918

TABLE 4.—*Output and value of mineral*

Year	Cement			Sand and Gravel	
	Natural	Portland			
	Quantity	Quantity	Value	Quantity	Value
34	35	36	37	38	39
	Barrels	*Barrels*		*Short Tons*	
1883	....	....	....	....	....
1884	*a*	....	....	....	....
1885	300,000	....	....	....	....
1886	226,000	....	....	....	....
1887	325,000	....	....	....	....
1888	332,055	....	....	....	....
1889	350,000	....	....	....	....
1890	363,117	....	....	....	....
1891	409,877	....	....	....	....
1892	472,876	....	....	....	....
1893	522,972	....	....	....	....
1894	466,267	300	$ 540	....	....
1895	491,012	750	1,325	....	....
1896	544,326	3,000	5,250	....	....
1897	510,000	15,000	26,250	....	....
1898	630,228	*e*	*e*	....	....
1899	537,094	53,000	79,500	....	....
1900	369,276	240,442	300,552	....	....
1901	469,842	528,925	581,818	....	....
1902	607,820	767,781	977,541	....	....
1903	543,132	1,257,500	1,914,500	*a*	*a*
1904	360,308	1,326,794	1,449,114	1,206,671	$ 689,740
1905	368,645	1,545,500	1,741,150	1,627,403	693,772
1906	365,843	1,858,403	2,461,494	2,657,559	1,043,041
1907	284,599	2,036,093	2,632,576	4,550,991	1,367,653
1908	188,859	3,211,168	2,707,044	6,657,748	1,503,022
1909	*b*	4,241,392	3,388,667	9,155,229	1,949,497
1910	*b*	4,459,450	4,119,012	8,586,508	1,730,795
1911	*b*	4,582,341	3,583,301	8,488,683	1,990,922
1912	*b*	4,299,357	3,212,819	6,957,901	1,929,822
1913	*b*	5,083,799	5,109,218	7,992,140	2,070,491
1914	*b*	5,401,605	5,007,288	7,696,130	1,859,519
1915	*b*	5,156,869	4,884,026	7,708,012	1,984,569
1916	*b*	3,642,563	3,386,431	8,365,225	2,587,437
1917	*b*	4,659,990	6,090,158	9,120,698	3,658,799
1918	*b*	3,594,038	5,695,186	6,355,406	3,980,124

a Statistics not available for this and earlier years.
b Concealed. Less than three producers.
e Prior to this date, the cement production was entirely slag cement manufactured by the Illinois Steel Co. at Chicago. Operations were abandoned by this company after their plant was destroyed by fire Feb. 3, 1898, but three new plants were under construction by other companies at La Salle.

products in Illinois, 1883 to 1918—Continued

Stone and Lime				Fluorspar		Year
Stone		Lime				
Limestone	Sandstone					
Value		Quantity	Value	Quantity	Value	
40	41	42	43	44	45	46
		Short Tons		*Short Tons*		
....	....	....	....	4,000	$ 20,000	1883
....	....	....	....	4,000	20,000	1884
....	....	....	....	5,000	22,500	1885
....	....	....	....	5,000	22,000	1886
....	....	....	....	5,000	20,000	1887
....	....	....	....	6,000	30,000	1888
a	*a*	....	....	9,500	45,835	1889
$2,190,607	$17,896	....	....	8,250	55,328	1890
2,030,000	10,000	....	....	10,044	78,330	1891
3,185,000	7,500	....	....	12,250	89,000	1892
2,305,000	16,859	....	*a*	12,400	84,000	1893
2,555,952	10,732	....	$387,973	7,500	47,500	1894
1,687,662	6,558	....	164,785	4,000	24,000	1895
1,261,359	15,061	....	145,294	4,000	32,000	1896
1,483,157	14,250	....	228,220	2,500	18,300	1897
1,421,072	13,758	....	127,156	*b*	*b*	1898
2,066,483	16,133	....	194,773	8,500	75,000	1899
1,881,151	19,141	....	246,575	3,690	8,900	1900
2,289,819	12,884	....	504,018	*b*	*b*	1901
3,222,608	32,200	....	485,644	18,360	121,532	1902
3,206,271	26,293	*a*	479,801	11,413	57,620	1903
3,151,890	47,377	108,881	461,088	17,205	122,172	1904
3,511,890	29,115	98,907	421,589	33,275	220,206	1905
2,942,331	19,125	121,546	534,118	28,268	160,623	1906
3,774,346	14,996	124,784	559,305	25,128	141,971	1907
3,122,552	12,218	92,549	393,951	31,727	172,838	1908
4,234,927	26,891	104,260	454,682	41,852	232,251	1909
3,847,715	5,710	113,239	503,581	47,302	277,764	1910
3,436,977	30,953	92,169	423,762	68,817	481,635	1911
3,808,784	32,720	98,450	394,892	114,410	756,653	1912
4,112,172	28,781	95,977	433,331	85,854	550,815	1913
2,861,340	72,738	87,603	383,989	73,811	426,063	1914
2,864,103	43,307	88,604	352,954	*b*	*b*	1915
3,362,751	40,343	80,012	369,038	*b*	*b*	1916
3,279,737	42,304	83,409	412,184	156,676	1,373,333	1917
2,951,045	*b*	64,672	535,090	132,798	2,887,099	1918

TABLE 4.—*Output and value of mineral*

Year	Natural Gas Gasoline		Zinc		Clay	
	Quantity	Value	Quantity	Value	Quantity	Value
47	48	49	50	51	52	53
	Gallons		*Short Tons*		*Short Tons*	
1902	....	....	....	....	52,152	$ 38,463
1903	....	....	....	....	71,038	73,842
1904	....	....	....	....	88,965	71,086
1905	....	....	*f*	*f*	127,728	120,410
1906	....	....	282	$ 33,840	139,704	131,272
1907	....	....	737	186,966	123,775	105,703
1908	....	....	1,717	161,398	117,082	114,482
1909	....	....	2,163	223,604	144,060	150,868
1910	....	....	3,549	383,292	188,803	190,896
1911	*b*	*b*	4,219	480,966	182,836	183,826
1912	*b*	*b*	4,065	560,970	176,558	192,663
1913	581,171	$ 67,106	2,236	250,432	194,937	204,037
1914	1,164,178	100,331	4,811	490,772	161,084	168,354
1915	1,035,204	80,049	5,534	1,372,432	163,904	169,320
1916	2,260,288	262,664	3,404	912,272	197,701	378,440
1917	4,934,009	866,033	4,267	870,468	195,693	789,589
1918	4,574,565	890,436	3,792	690,144	169,182	413,901

a Statistics not available for this and earlier years.

b Concealed. Less than three producers.

f There was a small but unrecorded production of zinc from 1900 to 1905. Prior to 1900, production was negligible.

products in Illinois, 1883 to 1918—Concluded

Tripoli	Pyrite		Silver		Mineral Waters		Year
Value	Quantity	Value	Quantity	Value	Quantity	Value	
54	55	56	57	58	59	60	61
Short Tons	*Short Tons*		*Fine Ounces*		*Gallons*		
....	....	....	....	....	508,016	$ 29,640	1902
....	....	....	....	....	1,118,240	149,978	1903
....	....	....	....	....	392,800	38,096	1904
....	....	....	....	....	425,756	47,995	1905
a	*a*	*a*	*a*	*a*	574,453	77,287	1906
b	*b*	*b*	2,852	$1,882	720,406	91,760	1907
b	*b*	*b*	2,051	1,087	685,763	58,904	1908
$ 39,262	5,600	$17,551	1,011	526	639,460	49,108	1909
33,390	8,541	28,159	2,022	1,092	1,117,620	83,148	1910
45,910	17,441	47,020	3,036	1,609	1,304,950	82,330	1911
27,339	27,008	62,980	4,731	2,909	1,143,625	74,445	1912
128,892	11,246	31,966	3,541	2,139	1,216,442	68,549	1913
59,394	22,538	59,079	2,112	1,168	1,760,030	81,307	1914
59,390	14,849	22,476	3,864	1,959	1,559,489	75,290	1915
82,968	20,482	51,432	5,684	3,740	1,777,741	94,056	1919
31,338	24,596	89,998	7,186	5,921	1,370,461	66,042	1917
18,902	24,369	85,659	8,171	8,171	921,953	43,448	1918

TABLE 5.—*Products and total mineral values, by counties, 1917*

County	Products (named in decreasing order of importance)	Total value
Adams	Lime, limestone, brick and tile, sand and gravel	$ 380,170
Alexander	Sandstone, tripoli, sand and gravel	80,344
Bond	Coal, sand and gravel, natural gas	327,275
Boone	Limestone, brick and tile, pottery, sand and gravel	30,852
Brown	Mineral water	(b)
Bureau	Coal, brick and tile, sand and gravel, natural gas	3,531,913
Calhoun	....	....
Carroll	Limestone, sand and gravel	1,835
Cass	Brick and tile, sand and gravel	16,124
Champaign	Brick and tile, natural gas	24,647
Christian	Coal, brick and tile	5,056,626
Clark	Petroleum, natural gas, limestone	[a]2,294,162
Clay	....	....
Clinton	Coal, petroleum, brick and tile	2,658,020
Coles	Petroleum	(b)
Cook	Brick and tile, limestone, pottery, lime, sand and gravel	7,947,409
Crawford	Petroleum, natural gas, sand and gravel, limestone	[a]8,365,682
Cumberland	Petroleum, natural gas	[a]660,535
DeKalb	Sand and gravel	(b)
DeWitt	Natural gas, brick and tile	853
Douglas	Brick and tile	(b)
DuPage	Limestone, brick and tile	71,323
Edgar	Brick and tile, petroleum, natural gas	9,890
Edwards	Brick and tile	181,864
Effingham	Brick and tile	(b)
Fayette	Brick and tile, sand and gravel	(b)
Ford	Sand and gravel	(b)
Franklin	Coal	24,826,209
Fulton	Coal, brick and tile, sand and gravel	5,910,756
Gallatin	Coal, brick and tile	164,706
Greene	Brick and tile, pottery, coal, clay, limestone	581,857
Grundy	Coal, brick and tile	1,203,950
Hamilton	Brick and tile	(b)
Hancock	Brick and tile, coal, sand and gravel	47,515
Hardin	Fluorspar, lead, silver, limestone	1,527,944
Henderson	Sand and gravel	(b)
Henry	Coal, brick and tile, mineral water	122,708
Iroquois	Brick and tile	62,037
Jackson	Coal, brick and tile	1,927,481
Jasper	Petroleum	(b)
Jefferson	....	....
Jersey	Brick and tile, limestone	63,167
Jo Daviess	Zinc, lead, sand and gravel	972,661
Johnson	Limestone, coal	(b)
Kane	Sand and gravel, pottery, brick and tile, limestone, mineral water	285,784
Kankakee	Brick and tile, limestone, lime	845,187
Kendall	Sand and gravel, limestone	71,830
Knox	Brick and tile, pottery, coal	1,313,272
Lake	Brick and tile, sand and gravel, mineral water	157,697
La Salle	Cement, coal, brick and tile, sand and gravel, quartz, clay, pottery, mineral water	10,852,775
Lawrence	Petroleum, natural gas, sand and gravel, brick and tile	[a]12,225,976
Lee	Cement, brick and tile, sand and gravel, limestone, natural gas	1,457,474
Livingston	Brick and tile, coal, sand and gravel, clay	1,247,102
Logan	Coal, sand and gravel, brick and tile, natural gas	1,323,942
McDonough	Brick and tile, pottery, petroleum, clay, coal	1,264,838
McHenry	Brick and tile, sand and gravel, mineral water	532,272
McLean	Coal, brick and tile	312,268

TABLE 5.—*Products and total mineral values, by counties, 1917*—Concluded

County	Products (named in decreasing order of importance)	Total value
Macon	Coal, brick and tile, sand and gravel	$ 982,444
Macoupin	Coal, natural gas, brick and tile, petroleum	[a]11,481,927
Madison	Coal, brick and tile, limestone, lime, sand and gravel, pyrite, mineral water, petroleum	9,553,424
Marion	Coal, petroleum, brick and tile	2,454,389
Marshall	Coal	1,134,268
Mason	Peat, brick and tile	([b])
Massac	Brick and tile	([b])
Menard	Coal, brick and tile	424,601
Mercer	Coal, brick and tile, sand and gravel	814,453
Monroe	Brick and tile	([b])
Montgomery	Coal, brick and tile	8,032,434
Morgan	Mineral water, brick and tile, petroleum, natural gas	47,575
Moultrie	Coal, brick and tile	496,096
Ogle	Quartz, sand and gravel, brick and tile, limestone	444,096
Peoria	Coal, sand and gravel, brick and tile, mineral water	3,137,042
Perry	Coal	5,209,006
Piatt	....	....
Pike	Limestone, sand and gravel, natural gas, brick and tile	58,468
Pope	Fluorspar, mineral water	1,864
Pulaski	Brick and tile	([b])
Putnam	Coal, sand and gravel	1,397,864
Randolph	Coal, limestone, sand and gravel, brick and tile, sandstone	2,408,277
Richland	....	....
Rock Island	Sand and gravel, coal, brick and tile, lime, mineral water, pottery	356,674
Saline	Coal, brick and tile	9,370,941
Sangamon	Coal, brick and tile	14,102,450
Schuyler	Coal, brick and tile, sand and gravel	34,815
Scott	Brick and tile, clay, coal	107,684
Shelby	Coal, brick and tile	318,490
St. Clair	Coal, brick and tile, limestone, sand and gravel	12,466,527
Stark	Coal, brick and tile	16,207
Stephenson	Limestone	13,206
Tazewell	Coal, brick and tile, sand and gravel, pottery	1,386,596
Union	Clay, tripoli	546,594
Vermilion	Coal, brick and tile, limestone, pyrite	8,688,396
Wabash	Petroleum, sand and gravel	69,651
Warren	Pottery, brick and tile, coal	639,120
Washington	Coal, brick and tile	1,515,059
Wayne	....	....
White	Coal, brick and tile, sand and gravel	305,921
Whiteside	Peat, sand and gravel, pottery	25,818
Will	Brick and tile, sand and gravel, limestone, coal, lime	2,972,173
Williamson	Coal, brick and tile	20,510,567
Winnebago	Sand and gravel, limestone, lime	328,995
Woodford	Coal, brick and tile	611,478

[a]The figures for natural gas and petroleum for certain counties have been estimated since some com, panies have no way of dividing the total figures into county units. An approximation of the values for Clark Crawford, Cumberland, Lawrence, and Macoupin counties was made by dividing the totals for two different large companies into the proportion of the number of wells in each county.

[b]Concealed, fewer than three producers reporting production.

TABLE 6.—*Products and total mineral values, by counties, 1918*

County	Products (named in decreasing order of importance)	Total value
Adams	Lime, brick and tile, limestone, sand and gravel	$ 356,956
Alexander	Tripoli, sandstone, sand and gravel	133,680
Bond	Coal, sand and gravel, natural gas	553,507
Boone	Pottery, limestone, brick and tile, sand and gravel	56,002
Brown	Mineral water	([b])
Bureau	Coal. brick and tile, sand and gravel, natural gas	3,860,197
Calhoun		....
Carroll	Limestone, sand and gravel	([b])
Cass	Sand and gravel, brick and tile	19,385
Champaign	Brick and tile, sand and gravel	6,595
Christian	Coal, brick and tile	6,798,345
Clark	Petroleum, natural gas, limestone	[a]6,207,764
Clay		....
Clinton	Coal, petroleum, brick and tile	3,567,561
Coles	Petroleum	13,268
Cook	Brick and tile, limestone, sand and gravel, pottery, lime	4,764,033
Crawford	Petroleum, natural gas, sand and gravel	[a]8,533,481
Cumberland	Petroleum, natural gas	[a]754,198
DeKalb	Sand and gravel	([b])
DeWitt	Natural gas	([b])
Douglas	Brick and tile	([b])
DuPage	Limestone, brick and tile	([b])
Edgar	Brick and tile, petroleum, natural gas	12,762
Edwards	Brick and tile	99,685
Effingham	Brick and tile	([b])
Fayette	Brick and tile, sand and gravel	56,515
Ford		....
Franklin	Coal	29,224,580
Fulton	Coal. brick and tile	6,722.486
Gallatin	Coal, brick and tile	496,326
Greene	Brick and tile, pottery, coal, clay	583,062
Grundy	Coal, brick and tile	1,089,994
Hamilton	Brick and tile	([b])
Hancock	Brick and tile, coal, sand and gravel	25,182
Hardin	Fluorspar, lead, silver, limestone	2,914,734
Henderson	Sand and gravel	([b])
Henry	Coal, brick and tile	121,132
Iroquois	Brick and tile	40,248
Jackson	Coal, brick and tile	2,757,684
Jasper	Petroleum	([b])
Jefferson		....
Jersey	Brick and tile, limestone	43,899
Jo Daviess	Zinc, lead, sand and gravel	539,934
Johnson	Limestone, coal	48,610
Kane	Sand and gravel, pottery, brick and tile, mineral water	203,699
Kankakee	Brick and tile, limestone, lime	656,888
Kendall	Sand and gravel	49,184
Knox	Brick and tile, pottery, coal	798,213
Lake	Brick and tile, sand and gravel, mineral water	14,303
La Salle	Cement, coal, sand and gravel, brick and tile, clay, quartz, mineral water, pottery	11,825,517
Lawrence	Petroleum, natural gas, sand and gravel	[a]16,526,334
Lee	Cement, brick and tile, limestone, natural gas, sand and gravel	990,211
Livingston	Brick and tile, coal, sand and gravel, clay	1,102,318
Logan	Coal, sand and gravel, petroleum, brick and tile, natural gas	1,242,800
McDonough	Brick and tile, pottery, petroleum, clay, coal	1,365,982
McHenry	Brick and tile, sand and gravel, mineral water	352,244
McLean	Coal, brick and tile	256,542

TABLE 6.—*Products and total mineral values, by counties, 1918*—Concluded

County	Products (named in decreasing order of importance)	Total value
Macon	Coal, brick and tile, sand and gravel	1,095,333
Macoupin	Coal, natural gas, brick and tile, petroleum	[a]16,021,122
Madison	Coal, brick and tile, limestone, lime, sand and gravel, pyrite, mineral water, petroleum	22,213,442
Marion	Coal, petroleum	2,741,697
Marshall	Coal, brick and tile, sand and gravel	1,327,768
Mason	Peat, brick and tile	([b])
Massac	....	....
Menard	Coal, brick and tile	485,713
Mercer	Coal, brick and tile, sand and gravel	1,021,715
Monroe	Brick and tile, limestone	([b])
Montgomery	Coal, brick and tile	9,796,886
Morgan	Mineral water, brick and tile, petroleum, natural gas	29,324
Moultrie	Coal, brick and tile	([b])
Ogle	Sand and gravel, quartz, limestone	397,391
Peoria	Coal, sand and gravel, mineral water, brick and tile	3,434,142
Perry	Coal	6,525,306
Piatt	....	....
Pike	Limestone, sand and gravel, natural gas, brick and tile	71,915
Pope	Fluorspar, mineral water	88,387
Pulaski	Brick and tile	([b])
Putnam	Coal, sand and gravel	1,451,447
Randolph	Coal, limestone, sand and gravel, brick and tile	3,609,571
Richland	....	....
Rock Island	Sand and gravel, coal, brick and tile, mineral water, pottery	259,196
Saline	Coal, brick and tile	13,522,259
Sangamon	Coal, brick and tile	18,677,051
Schuyler	Coal, brick and tile, sand and gravel	21,148
Scott	Brick and tile, clay, coal	53,610
Shelby	Coal, brick and tile	526,551
St. Clair	Coal, limestone, brick and tile, sand and gravel	17,090,637
Stark	Coal	([b])
Stephenson	....	....
Tazewell	Coal, brick and tile, sand and gravel	1,559,231
Union	Clay, tripoli	166,569
Vermilion	Coal, brick and tile, limestone, pyrite, sand and gravel	11,186,641
Wabash	Petroleum, sand and gravel	244,739
Warren	Pottery, brick and tile, coal	569,317
Washington	Coal, brick and tile	1,873,945
Wayne	....	....
White	Coal, brick and tile, sand and gravel	404,085
Will	Brick and tile, sand and gravel, coal, limestone, lime	3,348,797
Whiteside	Peat, sand and gravel	25,044
Williamson	Coal, brick and tile	26,149,223
Winnebago	Sand and gravel, limestone, lime	196,871
Woodford	Coal, brick and tile	530,710

[a]The figures for natural gas and petroleum for certain counties have been estimated since some companies have no way of dividing the total figures into county units. An approximation of the values for Clark, Crawford, Cumberland, Lawrence and Macoupin counties was made by dividing the totals for two different large companies into the proportion of the number of wells in each county.

[b]Concealed, fewer than three producers reporting production.

Almost every county in the State reports some sort of mineral product and many of the more important industries, as coal, oil, clay products, stone, and sand and gravel, are represented very widely among the counties. Inspection of Figure 2 and of Tables 5 and 6 will serve to illustrate these facts.

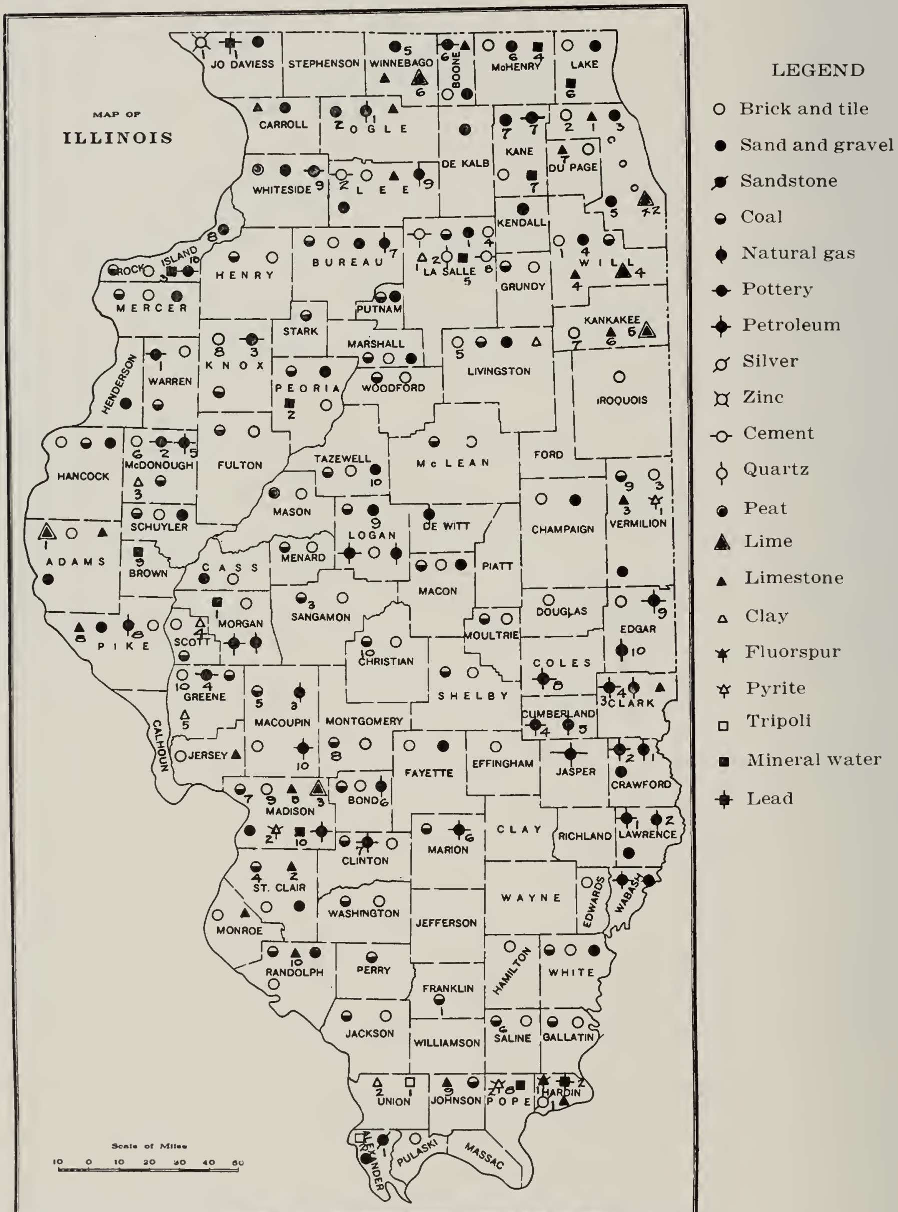


FIG. 2. Map showing graphically the mineral industries of each county for 1918, and the ranks of the counties in the industries.

The rank of an industry in a county is indicated by its relative position from left to right within the county and its rank in the State is shown by the figure accompanying the symbol. For example, the coal symbol in the northwest corner of Madison County represents the most important industry in the county and the seventh in value in the State.

Scheme of Report

One of the ways in which the Survey performs its duty of keeping in close touch with activity of the mineral industries, is by study and publication of statistics of mineral production. The custom of publishing annual or biennial reports on the "Mineral Resources" is carried on by this report for the years 1917 and 1918, but the scheme of presentation has been changed.

In previous years the "Mineral Resources" reports have discussed the various mineral industries in about the order of decreasing importance from the standpoint of value. The order adopted for this one report calls for a discussion of the oldest industries first and the youngest last. It is hoped that historical perspective will thus be achieved, and the purpose of this report, namely, to emphasize the progress of development of mineral industries in Illinois, will thus be furthered.

PERIODS OF DEVELOPMENT OF THE STATE AND ITS MINERAL RESOURCES

Just as the history of the State divides itself into four sub-equal periods, so do the mineral industries readily fall into a similar grouping: the frontier or pioneer period, 1818 to 1848; the era of the Civil War, 1848 to 1870; the time of industrial growth, 1870 to 1893; and a fourth period which for lack of a more distinctive name, may be called "modern," 1893 to 1918.

Naturally during the frontier period and the pre-1818 years, development of mineral wealth was unimportant. Of the long list of minerals now produced, probably lead alone was among the mineral resources that the explorers and earliest settlers desired and sought for. The glamour of gold and silver doubtless occupied the central position in the background of the explorer's mind, and Indian tales of pieces of copper found lying on the surface as well as deposits of lead worked by the Indians prior to the coming of the white men, long inspired the hope of great metal mines. The early settlers' real but perforce inadequate recognition of the value of the coal deposits kept them on the lookout for easily accessible outcrops; and salt as an immediate necessity, and iron as a later need were early developed. But beyond the metals, coal, and salt, the desires of the explorers and pioneers did not go and little did they realize that the one of these they looked upon with least interest was later to be the foundation of the State's industrial prosperity.

It was not until well into the second period, specifically not until the sixties, that coal production increased perceptibly and meanwhile other industries lagged even more. With the passing of the second quarter of the century the beginnings of great mineral development were beginning to be apparent. But it was not until the close of the third quarter-century that

the variety and value of the developed resources began to give real promise of their present magnitude.

REASONS FOR DELAYED DEVELOPMENT

Natural though it was that large development of mineral wealth should not accompany early settlement, still for the sake of clearness of conception, it is worth while to analyze some of the reasons for the slowness with which Illinois responded to the opportunities that lay hidden beneath and within her soils and rocks.

The adventurous early visitors to the region may not have been willing to stay themselves long for minerals less alluring than gold and silver, but with the arrival of the first home-makers, unafraid of toil and willing to win a livelihood more slowly, lack of development can not be laid to the unromantic character of the mineral resources Illinois could offer. The early lack of development was due rather to certain geologic and geographic conditions and to lack of transportation.

Transportation Problems

Transportation problems were so intimately related to the development of the coal industry in Illinois that detailed consideration of this question is reserved for discussion of that industry. At this point it will suffice to point out that most of Illinois' mineral products are relatively bulky and that obviously therefore the transportation problem was one that had to be solved before production for use distant from the source could be economically possible.

Geologic Conditions

To the greatest depths explored by shaft and drill, the rocks beneath the surface in Illinois are all sedimentary, that is they originated as deposits or sediments laid down in ancient seas which at different times covered the whole or parts of the area. Layers of sand, clay, broken shells, vegetable material, or mixtures of two or more of these varieties of sediments became hardened by cementation and by pressure of later overlying sediments into beds of solid rock—sandstone, shale, limestone, and coal corresponding to the original layers of sand, mud, shells, and vegetable material.

By the close of what geologists call Paleozoic time, several million years ago, the last of the seas in which these sediments were laid down had disappeared, and from that time until the present, Illinois was almost entirely continuously above sea level. Ten thousand feet more or less of flat-lying rocks and sediments had accumulated in the Illinois area during Paleozoic time. At the close of the Paleozoic era this whole great thickness was warped, in most places gently, until the sediments and rocks were no longer flat-lying but had the form of the bowl of an extremely shallow and somewhat misshapen spoon, the rim of which happened to conform roughly to

the outline of the State. During the long land period from the close of the Paleozoic era to the present, the rim, that is the higher portions, of the "spoon" were lowered by wind, streams, and frost more rapidly than were the lower parts at the center of the "spoon," until finally the whole area was reduced to a gently rolling plain, and the shape of the surface no longer indicated the warping. The structure of the remaining rocks can still tell the tale however—the oldest come to the surface about the borders of the State marking the spoon rim, and dip gently and successively beneath younger ones towards its center, which was the axis of the deformation.

Recently, as compared with the Paleozoic warping, but actually many thousands of years ago, great continental ice sheets hundreds of feet thick spread of their own weight at least five times over large areas of Illinois, each time curtaining the old surface more and more thickly with clay, gravel, and sand ("glacial drift"), which was left by the ice when climatic changes caused the glaciers to melt. All the State was covered at least once by ice sheets with the exception of two small areas, one the northwest corner of the State, including all of Jo Daviess and parts of Carroll and Stephenson counties, and the other the extreme southern part, including all of Pope, Hardin, Pulaski, Massac, Union, and Alexander, and parts of Jackson, Saline, and Gallatin counties.

On the west side of the State, Mississippi River and its larger tributaries have cut through the drift in many places, making accessible the underlying rocks and their contained mineral resources; and so it is too along the Wabash to some extent. Remembering the unglaciated northwestern corners and southern end of the State, the generalization may then be made that in a belt around the west, south, and southeast, there is more chance for exposure of the mineral resources found in hard rocks than there is in the central part of the area where the drift is still thick and relatively unbroken in most places.

Thus the vast resources of the heart of the State were concealed from the view of the early settlers by geologic conditions, and development of resources tended to begin earlier nearer the borders of the State, than in the interior.

Geographic Conditions

THE EFFECT OF THE FORESTS

The effect of the forests, the distribution of which is shown in figure 3, was somewhat contradictory. On the one hand, population spread up the main valleys attracted by the abundance of game, water, and wood, and thus settlers were early led into the very parts of the State where geologic conditions made most easily available such important mineral resources as stone, coal, lead, and salt. But on the other hand the very presence of the forests was a hindrance because it slowed up thorough exploration, at least for a

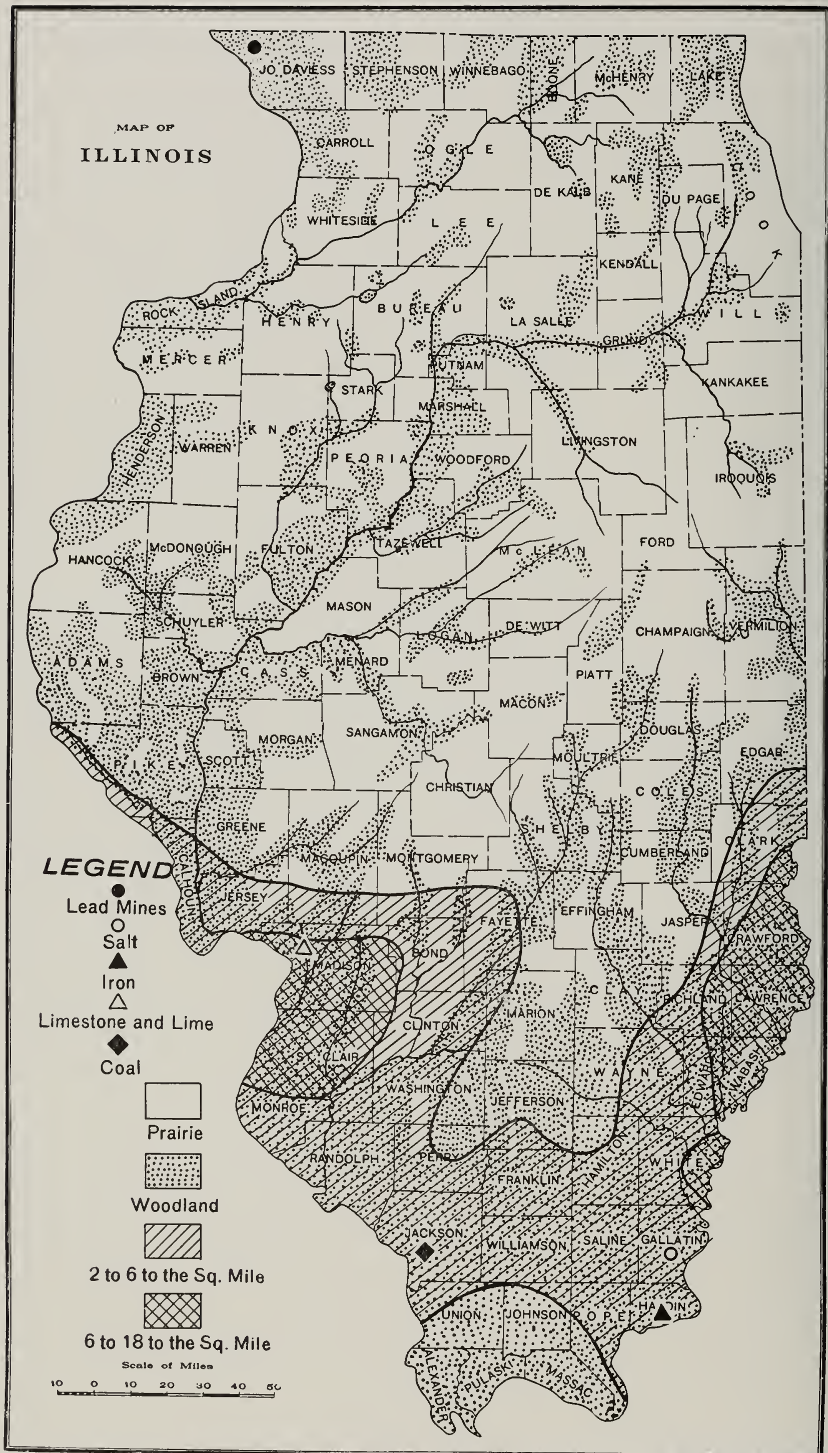


FIG. 3. Map of Illinois showing the original wooded areas, the distribution of population in 1820, and the location of early mineral production.

short time. All in all, however, it was the first effect that was the more powerful and in general it is clear that the forests furthered relatively early utilization of mineral resources.

THE EFFECT OF THE PRAIRIES

Development of the mineral resources of the central drift-covered, or "basin" part of Illinois had to wait until population spread out of the forested stream valleys onto the treeless and originally ill-drained prairies which are typical of that section of the State.

Barrows says[1] that the prairies aroused the wonder of all early travelers but "were generally shunned by the first comers for several reasons: (1) absence of trees was thought to mean that they were infertile; (2) timber was imperatively needed for buildings, fences, and fuel; (3) they did not afford running water for stock or mills, while the lack of fuel left steam mills out of the question; (4) there was no protection from the bitter winds of winter which above all else made that season disagreeable. Men and cattle have even been known to perish in storms on the open prairies; (5) to the farmer the prairies with their tough sod and matted roots constituted a new and altogether unknown problem."

If only the farmers had known that within and beneath the mask of drift of the prairies was stored not only fuel and water in abundance, but also that the drift itself was one of the richest sources of plant food in the world, the prairies need not have waited for about half of the century for their share of population. Commonly south of the latitude of Rock Island an abundance of coal at a practical depth for mines was to be had; in widely distributed strata and lenses of sand and gravel that constituted part of the drift, water was stored in plenty; and the upper part of the drift, once the sod was broken, formed one of the richest soils in the world. But so difficult were prairie conditions for the pioneer, that general development of mineral resources was markedly retarded in the heart of the State. An exception is seen in the early settlement and activity in the La Salle region where unusual geologic conditions made easier both discovery and marketing of mineral deposits and products.

MINERAL RESOURCES AND INDUSTRIES

Pre-1818 Period

The earliest minerals utilized by man in Illinois were of course water and soils, but both are so universally needed, used, and distributed that they are not to be considered as commodities in the ordinary sense.

Salt, lead, limestone, ore, and coal were mineral resources of later development, but they too belong to the pre-1818 group (fig. 3).

[1]Barrows, Harlan H., Geography of the middle Illinois valley: Ill. State Geol. Survey Bull. 15, p. 77, 1910.

SOILS

The value of iron and of coal may be emphasized as strongly as possible, and these two may be used as the measure of a nation's wealth; but it must never be forgotten that after all the ultimate dependence of man is both directly and indirectly on the soils. They constitute a mineral resource whose value is immeasurable—mineral because soil is based on finely ground minerals, and immeasurable because it is an original source of the substance of life. In the matter of soils, the events of Illinois geological history had particularly favorable results. For, far from removing every vestige of soil or leaving a meager stony covering as was left over New England, the glaciers brought to Illinois many different kinds of rock material, the bulk of it ground to fineness, but still possessed of all the original ingredients of fresh rock, and capable of constant liberation of plant food. Different indeed is such a soil from one that is a residual from decayed rock and has therefore lost much of its mineral plant food by the time it has reached the stage of comminution that renders it texturally suited for crop growth.

Mineral in origin though soils may be, so unequalled is their importance that their study is a science in itself. And so with the reminder that Illinois soil is its most valuable mineral resource, it will be left to the agriculturists.

WATERS

It is true that statistics are given for a nominal water industry (Table 4), but these figures give no conception of the true amount and value of water taken from the rocks and soils. Compare them, for example, with the estimate made by Leverett in 1896, when population was smaller than it is now, that "the total supply from [shallow wells] is about 840,000 barrels for household consumption and 700,000 barrels for stock, or about 1,500,000 barrels per day. About one-half the population of the State is thus supplied with water for cooking and drinking, the other half being supplied mainly from Lake Michigan and from the streams, deep wells furnishing the supply for but a small part of the population."[1]

It is a significant fact that even in the area which is dominated by the Lake, deep (or artesian) wells are sources of water for industrial purposes. It would seem that the original cost of drilling a two-thousand-foot well with its smallest diameter from six to twenty inches, and the continual expense of upkeep and pumping would eliminate wells as a source of supply in a district where water is as abundant as it is in the region of Lake Michigan. And yet in Chicago during the summer of 1914 there were in active service 125 wells over 1,000 feet deep, with a pumpage of over 30,100,000 gallons per 24 hours; and within a circle of a half-mile radius in the stock-

[1]Leverett, "The Water Resources of Illinois," in United States Geological Survey, Seventeenth Annual Report, 1896, part 2, p. 769.

yards district 26 wells delivered 13,450,200 gallons, or 44.3 per cent of the total daily deep-well pumpage in the city.[1]

Industries in other parts of the State are forced to depend upon deep wells for water supplies, but such statistics as these for the Chicago district where an alternative source is at hand, demonstrate clearly the real importance and value of deep underground water supplies. Deep-well sources are destined to become of ever-increasing importance, especially outside the Lake cities, as a direct consequence of the increasing danger of the pollution of shallow sources that accompanies the growth of population.

SALT

After waters and soils, probably the next resource used by human beings prior to 1818 was salt. The history of this industry is especially interesting because of its relationship to the settlement of the Mississippi Valley. Before some of the present most important deposits of salt were known, extreme southern Illinois was one of the very few, and of these few the most important of the sources of salt west of the Appalachians. Indeed, so difficult was it to obtain, that for years the government reserved from sales all lands containing salt springs, and the historic Gallatin County brines were worked under the direction of army officers. Many saline springs pour brine into all the water courses of Saline and Gallatin counties, but only in Gallatin County about one mile south of the town of Equality (fig. 3) on the north side of Saline River was it of sufficient strength to be profitable.

Near the site of these springs is the "Half-moon,"[2] a semi-circular excavation as its name implies, 100 yards in diameter and six to eight deep, believed to have been made by buffaloes or other wild animals that probably congregated in great herds to lick the salt. Still earlier, mammoths and mastodons visited the swamp for the sake of the salt as is evidenced by the numerous teeth, and sometimes even parts of skeletons embedded in the soil. The Indians, too, visited the site, for around the springs fragments of Indian pottery were formerly very plentiful. "To judge from the curvature of some of these fragments, the vessels to which they belonged were not less than 4 or 5 feet in diameter, a size truly astonishing made as they appear to have been of common clay and fragments of fresh water shells. From the large size of these pots it is natural to infer that they were used by a pre-historic race of salt makers."[3]

A vivid description of the early historic use of the brines in an old report emphasizes the vital importance and the truly industrial character of its production in contrast to what was little more than haphazard utilization in the case of water, and building stone. "The brine then used required from 125 to 280 gallons to make one bushel (50 pounds) of salt. Between one and

---

[1]Bulletin 34, Ill. Geol. Sur.

[2]Cox, E. T., Geology of Gallatin County: Geol. Survey of Illinois, Vol. VI, p. 213, 1875.

[3]Ibid., p. 216.

two thousand hands were employed, and the yield of the works has been estimated at 80 to 100 bushels of salt per diem. So greatly was the demand beyond the power of the works to supply that . . . . applicants for salt coming from Tennessee, Kentucky, Indiana, and other parts of the country were regularly ticketed, and could be supplied only by awaiting their proper turn. No one thought of stopping for the drainage of the salt crystals, but all were glad to receive it as soon as it was cool enough to handle and to start off with their pack horses loaded with sacks of salt from which the water trickled as they journeyed home. The fuel required to evaporate such an immense amount of water stripped the country of timber for miles around, and the expedient was resorted to of conveying the brine for miles in wooden pipes to the rapidly receding forests. The idea never once occurred to those early salt makers that the five-foot bed of coal through which their wells were generally dug could furnish, ready at hand, a never failing supply of the best and cheapest fuel."[1]

With the development of the strong brines on the Kanawha River in West Virginia, beginning about 1807 or 1808 and with the discovery of rich brines in Pomeroy, in Ohio, the Saline works were no longer able to run with profit and the industry in Illinois died. In 1850 it was revived there and brines were worked contemporaneously in other parts of the State as at Brownsville, Jackson County, at Central City, Marion County, and on Salt and Middle Forks. But even though the combined production from these sources surpassed that of the early Gallatin days, the industry of the later years could in no measure equal that of the pioneer period in its comparative importance and far-reaching effects on settlement.

Since 1896 no production of salt from Illinois has been recorded and probably none will be produced again.

LEAD, ZINC AND SILVER

The lead and zinc industry, too, had its beginnings prior to 1818 (fig. 3), and throve during those early days. Like the salt industry, it declined and although small amounts of lead and zinc still come from northern Illinois and, as a by-product of the fluorspar mining operations, from southern Illinois, this industry is now of comparatively little importance.

NORTHERN ILLINOIS

The date of the earliest utilization of the lead deposits of the upper Mississippi region is unknown, but from the evidence of crude mining tools found in abandoned drifts by the earliest white miners, it is believed that the Indians had used the lead even prior to the advent of the French; and further, Hennepin's map, dated 1687, shows native mines near Galena. During the entire eighteenth century Indians did most of the mining and sold it to traders. "The savages would load the ore at the bottom of the inclined

[1] Op. cit. pp. 214-215.

shaft into deerskin bags, and hoist or drag it to the surface by means of long thongs of hide. The lower work was performed almost entirely by old men and squaws. Large logs would be placed on the ground and smaller pieces of wood piled around, and the ore heaped on. The fire would be set in the evening and in the morning shapeless pieces of lead would be found."[1] Later, smelting methods improved. "A hole was dug in the face of a piece of sloping ground about 2 feet deep, and as wide at the top. This hole was shaped like a mill hopper and lined with flat stones. At the bottom of the hopper which was 18 inches square, narrow stones were laid across grate wise. A trench was dug from the sloping ground inward to the bottom of the hopper. . . . . The hopper was filled with ore and fuel. When the latter was ignited the molten lead in a few minutes fell through the stones at the bottom of the hopper and thence was discharged through the trench over the earth. The fluid mass was then poured into an awkward mold and as it cooled was called at 'plat,' weighing about 70 pounds, very nearly the weight of a 'pig' of later days."[2]

Friction over trading rights between the French and Indians on the one hand and the English and later the Americans on the other, kept the lead region in continual turmoil during the eighteenth and the early part of the nineteenth century and made mining anything but active and systematic. In 1816 however, the Indians ceded to the government for mining an area fifteen miles square on Fever River, and in 1823 Colonel James Johnson began the first of the systematic mining when he brought experienced miners, and 150 slaves, and adequate tools, and under military protection undertook development of the deposits near Galena under a 3-year lease.

At once prospectors and squatters began to pour into the region. "Lieutenant Thomas reported the number of American miners in Fever (Galena) River diggings in July, 1825, as 100, and in December as 151. In the spring of 1826 the number in the vicinity of Galena was nearly 200. This increased to 400 by June and to 550 in the fall. In four years this sequestered spot literally swarmed with miners, smelters, merchants, speculators, and gamblers of every description. By 1827 the workmen in the mines numbered 1,600 and in 1830 some 2,111 people were enumerated in Jo Daviess County alone."[3]

Production figures for the years 1823 to 1829 are given, followed by statistics by ten-year periods through 1920.

---

[1]Schockel, Bernard H., History of development of Jo Daviess County: Ill. State Geol. Survey Bull. 26, p. 179, 1916.

[2]Ibid., p. 180.

[3]Ibid., pp. 184-185.

TABLE 7.—*Lead production in the Fever River Mines, 1823 to 1829*

	Tons
1823	168
1824	88
1825	332
1826	479
1827	2,591
1828	5,553
1829	6,672

TABLE 8.—*Lead production of the upper Mississippi Valley region, 1821 to 1920, by decades*

	Tons
1821-30	23,244
1831-40	55,718
1841-50	215,979
1851-60	161,334
1861-70	84,700
1871-80	49,000
1881-90	10,000
1891-00	10,000
1901-10	25,088
1911-20	40,278

The abrupt decline in production after 1850 is attributed to several causes: "(1) The richer deposits began to give out. (2) By 1850 the shallower diggings were largely exhausted. . . . . (3) The discovery of gold in California in 1848 diverted from Galena the flow of mining immigrants and also lured to California many miners from the district. (4) Many of the younger miners sought their fortunes [elsewhere] . . . . (5) The reduction of the import duty on lead . . . . (6) The increasing abundance . . . . of zinc ore as mining reached greater depths. (7) The great demand for laborers in railroad construction and other internal improvements."

With the decline of lead production, zinc began to come into prominence because of the development of satisfactory smelters. Between 1850 and 1870, three large smelters, one at La Salle, a second at Mineral Point, Wisconsin, and a third at Peru were built to smelt Upper Mississippi Valley zinc.

The mineral deposits of the Galena region had great local and at times even national importance. Some of the effects may be listed as follows:

1. Hastened exploration.
2. Hastened removal of Indians and more rapid development of region.
3. Hastened development of St. Louis, New Orleans, and Buffalo, where lead ore was shipped and manufactured; was responsible for beginning of Mineral Point, Dubuque, Galena; furthered the growth of La Salle, Peru, and Mineral Point.

4. Made contest over position of boundary line between Wisconsin and Illinois more intense.
5. Introduced powder and bullets to Indians.
6. Introduced slaves to the State.
7. Influenced establishment of the early stage line between Galena and Chicago (1829).
8. Influenced the building of the Galena and Chicago Union Railroad, 1855.
9. Invigorated steamboat trade on the Mississippi.

SOUTHERN ILLINOIS

Lead, associated with fluorspar in vein formation, was discovered in Hardin County in 1842 near the site of the present Rosiclare mine and development of the deposit was undertaken. From that time until 1870 or thereabouts this and similar veins in that district were mined chiefly for their lead content. But as various industries began to demand fluorspar in increasing amounts, lead production became a side issue in the main business of fluorspar mining. It is interesting to note that in spite of the fact that southern Illinois lead is at present but a by-product, it has nevertheless amounted to 46 per cent of the State's total tonnage in the past ten years, northern Illinois reporting 54 per cent.

Whereas the lead ores of northern Illinois are associated with zinc ore in commercial amount, the southern Illinois veins contain so little zinc mineral that its separation has not been considered commercially practicable. And whereas the lead ores of northern Illinois are not argentiferous, those of southern Illinois run as high as 14 ounces of silver to the ton of lead concentrates. Statistics of silver production are found in tables 4 and 9.

Table 9.—*Production and value of lead, zinc, and silver in Illinois by districts, 1909-1918*

Year	District	Lead		Zinc		Silver	
		Quantity	Value	Quantity	Value	Quantity	Value
		Short tons		*Short tons*		*Fine ounces*	
	Northern Illinois.......	88	$ 7,566	2,163	$ 223,604	....	....
1909	Southern Illinois.......	207	17,804	....	....	1,011	$ 526
	Total..............	295	$ 25,370				
	Northern Illinois.......	101	8,888	3,549	383,292	....	....
1910	Southern Illinois.......	272	23,936	....	....	2,022	1,092
	Total..............	373	$ 32,824				
	Northern Illinois.......	625	56,250	4,219	480,966	....	....
1911	Southern Illinois.......	339	30,510	....	....	3,036	1,609
	Total..............	964	$ 86,760				
	Northern Illinois.......	687	61,830	4,065	560,970	....	....
1912	Southern Illinois.......	595	53,550	....	....	4,731	2,909
	Total..............	1,282	$115,380				
	Northern Illinois.......	588	51,744	2,236	250,432	....	....
1913	Southern Illinois.......	371	32,648	....	....	3,541	2,139
	Total..............	959	$ 84,392				
	Northern Illinois.......	492	38,376	4,811	490,722	....	....
1914	Southern Illinois.......	225	17,550	....	....	2,112	1,168
	Total..............	717	$ 55,392				
	Northern Illinois.......	495	46,530	5,534	1,372,432	....	....
1915	Southern Illinois.......	459	43,146	....	....	3,864	1,959
	Total..............	954	$ 89,676				
	Northern Illinois......	462	63,756	3,404	912,272	....	....
1916	Southern Illinois.......	610	84,180	....	....	5,684	3,740
	Total..............	1,072	$147,936				
	Northern Illinois......	594	102,168	4,267	870,468	....	....
1917	Southern Illinois.......	845	145,340	....	....	7,186	5,921
	Total..............	1,439	$247,508				
	Northern Illinois.......	1,413	200,646	3,792	690,144	....	....
1918	Southern Illinois.......	860	122,120	....	....	8,171	8,171
	Total..............	2,273	$322,766				

TABLE 10.—*Tenor of lead and zinc ore and concentrates produced in Illinois, 1917 and 1918*

	1917	1918
NORTHERN ILLINOIS		
Total crude ore . . . . . *short tons*	327,340	280,900
Total concentrates in crude ore:		
Lead . . . . . *per cent*	.24	.66
Zinc . . . . . *per cent*	5.56	4.67
Metal content of crude ore:		
Lead . . . . . *per cent*	.18	.50
Zinc . . . . . *per cent*	1.63	1.60
Average lead content of galena concentrates . . . . . *per cent*	75.4	75.5
Average zinc content of sphalerite concentrates . . . . . *per cent*	29.3	35.7
Average value per ton:		
Galena concentrates	$99.83	$87.09
Sphalerite concentrates	$26.18	$28.72
SOUTHERN ILLINOIS		
Average lead content of galena concentrates . . . . . *per cent*	70.7	70.0
Average value per ton of galena concentrates	$99.10	$83.52

LIMESTONE

The stone industry, based on another mineral resource used prior to 1818, has persisted to the present, the 1918 production having a value of almost three million dollars. Large though this figure is, the increase in the past quarter of a century is surprisingly small when compared with that of other minerals. The reasons are probably that Portland cement and clay products, such as brick and terra cotta, have been largely substituted for stone in construction work; and that the Bedford limestone quarries of Indiana, opened during the nineties and very favorably situated with reference to the Illinois market, supply a product recognizedly superior to Illinois limestones.

Since 1890 clay products have doubled their values, and cements have increased fifteen times over; and as much of this production has been substituted for stone in structural work, it is not surprising that Illinois' rank in production of building stone is now only fourteenth, although for many years prior to 1896 the State ranked first in the country for marketed production of that class of stone.

The general absence of surface limestone over the broad central portion of the State (due to the geologic structure and the prevalence of glacial drift deposits there) means that the State must continue to look chiefly to border counties for structural limestone and for road metal. The latter is of increasingly vital importance to the prairie population since the advent and rapid increase in the use of automobiles has forced the construction of good roads.

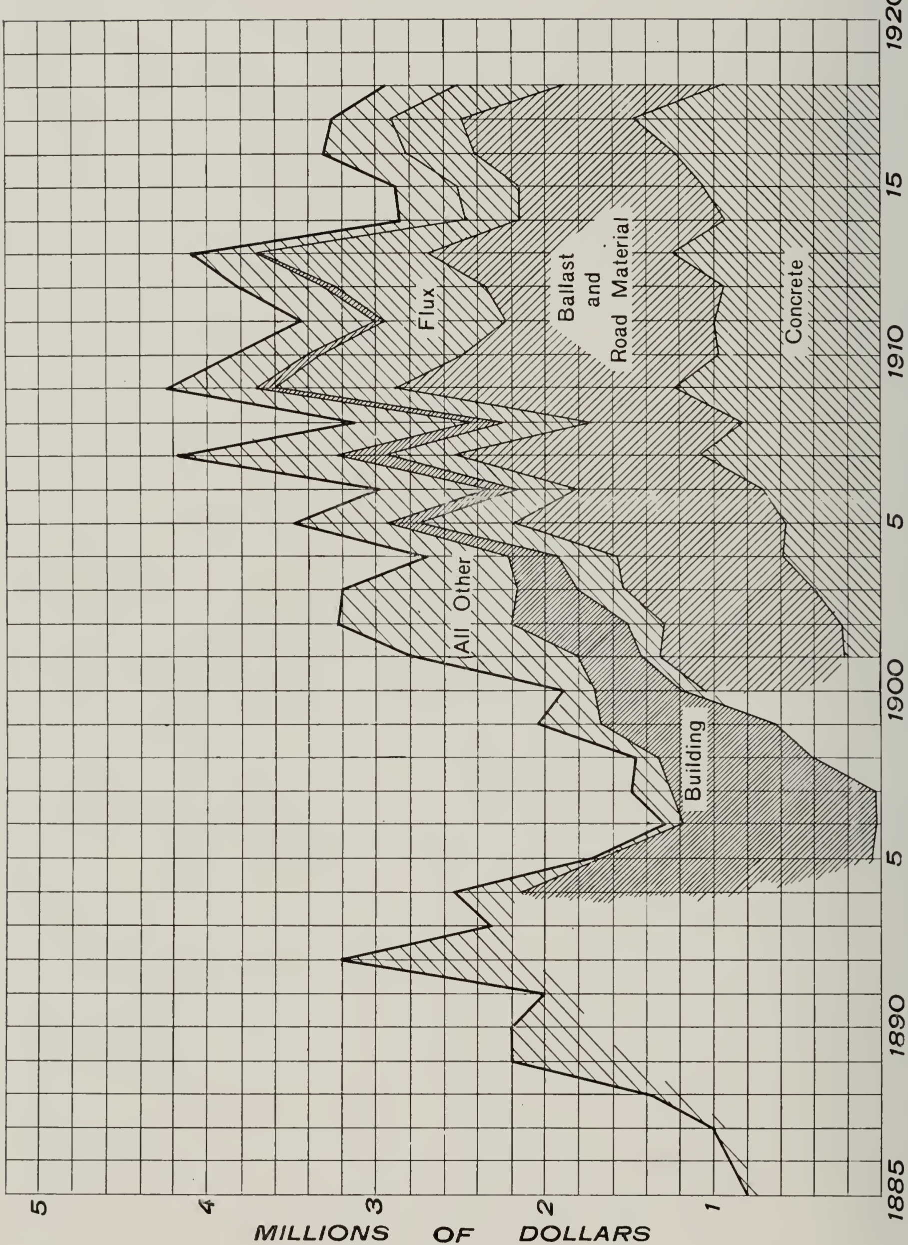


Fig. 4. Value of limestone production of Illinois according to uses, 1885-1918.

TABLE 11.—*Relative importance of the limestone production districts, 1917 and 1918*

Districts	*1917*	*1918*
Chicago	$2,427,385	$2,134,718
Mississippi River	460,482	522,482
East central	228,784	203,140
Northern	110,833	40,630
Southern	52,253	50,075
Total	$3,279,737	$2,951,045

For the past fifty years, the few available statistics indicate that the Chicago district, comprising Cook, Will, and Kankakee counties, has led all others, and that the Mississippi River district has consistently held second place.

Each of these districts has limestone deposits in plenty and of good quality for construction purposes; and each has adequate and cheap transportation both by rail and by water, the Mississippi for the latter district and the Drainage Canal for the former. The reason for the marked supremacy of the Chicago district is to be found not in advantages of this sort but rather in the greater demand, resulting from the much greater concentration of population in the Chicago area.

In the earlier half of the century, however, the relative importance of the two districts was just the reverse, because the spread of population was guided by the Mississippi River, and the population and demand were greater in that part of the State.

Although the distribution of the limestone industry and the relative importance of the districts has been comparatively stable since the Chicago area came into supremacy, the uses of the product have changed remarkably (fig. 4). For example, whereas in 1890 approximately half of the total stone production was building stone, in 1917 almost the same proportion was sold for concrete and more than half as much again for road making and as railroad ballast. Due to the change of construction material, thus indicated, Illinois has fallen in production of building stone from first to last place, and from more than a million dollars to about ten thousand, during a period when in every other use there has been a marked increase.

Of recent years a very large percentage of the stone produced in Illinois has been sold as crushed stone for concrete, road metal, and railroad ballast. In 1917, for example, 75 per cent went for these purposes and in 1918, 65 per cent. Although 47 States reported production of crushed stone in 1917, Illinois led them all. In 1918, however, Ohio and New York regained first and second place, with Illinois in third rank. All three states reported decreased production of crushed stone in 1918, but Illinois' decrease amounted to 38 per cent, whereas New York's and Ohio's were only 34 per cent and 4 per cent respectively. The country-wide falling off of crushed stone production, averaging 27 per cent, was due largely to the

discontinuance of practically all road construction in 1917 and 1918 except that necessary for repairs of roads on the main line of transportation and the building of new roads for war purposes. The signing of the armistice came so late in 1918 that there was time for little more than plans for resumption of repair and new work, and the expected reaction of these plans in increasing stone production was not noticeable in 1918.

In Table 12 will be found statistics of prices of crushed stone since 1905.

TABLE 12.—*Average price per short ton of crushed stone in Illinois and the United States, 1905-1918*

Year	Road metal		Railroad ballast		Concrete		Total	
	Illinois	U. S.	Illinois	U. S.	Illinois	U. S.	Illinois	U. S.
1905	$0.67	$0.64	$0.45	$0.48	$0.64	$0.67	$0.57	$0.59
1910	.56	.64	.53	.49	.65	.65	.58	.59
1907	.63	.66	.63	.52	.75	.71	.66	.63
1908	.57	.62	.50	.52	.49	.65	.52	.61
1909	.91	.67	.40	.48	.52	.64	.60	.61
1910	.89	.62	.48	.48	.46	.64	.55	.59
1911	.48	.62	.38	.50	.52	.65	.50	.59
1912	.41	.60	.42	.49	.47	.67	.43	.59
1913	.47	.63	.42	.51	.61	.67	.48	.61
1914	.49	.61	.42	.51	.49	.68	.47	.61
1915	.46	.60	.42	.50	.49	.65	.47	.60
1916	.44	.63	.40	.49	.48	.67	.45	.61
1917	.58	.75	.46	.56	.57	.78	.55	.72
1918	.65	.97	.64	.77	.72	1.05	.68	.95

As would be expected the average prices for Illinois vary more than do those for the United States as a whole. Perhaps the most significant generalization that can be made about the table is that from 1905 to 1910 State prices tend to be equal to or higher than average country-wide prices, whereas from 1911 on the tendency is decidedly for lower prices in Illinois. The increases in 1917 and 1918 were general over the whole United States, as a result of increased supply and labor costs.

LIME

Probably almost as old as the limestone industry is that of lime burning. The superior quality of the limestone in the vicinity of Alton, the favorable geographic location of that city with reference to centers of population in the early days, the cheap river transportation, and the abundance of fuel, both wood and coal, combined to make the Alton district leader for many years. An old report[1] describes the beginnings and growth of the industry in a quotation from the Alton Courier of November 28, 1857.

[1]Worthen, A. H., Geology of Madison County: Geological Survey of Illinois, Vol. I, p. 324, 1866.

"The first lime made in the city [Alton], of which we have any record, was manufactured in Hunterstown in the year 1815, by Colonel Jacob Judy. The manner of its manufacture was in keeping with the primitive style of those early times. It was simply this: Large log heaps were made, and the rock being placed upon them, they were fired, and as the logs burned to ashes, the rock was transformed into lime. Lime continued to be made in this way as occasion and necessity demanded, until 1818, when it was manufactured in kilns. The first kiln was erected in Hunterstown by Major C. W. Hunter, who leased it to the Honorable George Smith and Thomas G. Hawley, now of Upper Alton. These gentlemen manufactured lime to a considerable extent, which they were under bonds to sell at not more than 25 cents per bushel . . .

"The manufacture of lime continued to be carried on with more or less activity until 1847. In this year the barreling and exportation of lime was commenced and from that day to this the business has prospered and grown, and is yet increasing day by day. Its present extent can perhaps be judged of by a few facts and statistics.

"Since the first of March last [1857], there has been manufactured 121,900 barrels, of which 48,400 barrels have been shipped by railroad in bulk. The balance, 73,500 barrels, has been shipped and sold in barrels, thus affording a large demand for cooperage work. There are twenty kilns now in operation of which five are patents. These kilns give employment in various ways to not less than four hundred men, aside from the cooperage required by them."

By the seventies the center of population, and therefore the principal market, was shifting northeast, and the Alton district lost its leadership. However, once the early abnormally rapid growth of the northeastern counties was over, the Mississippi district was reinstated as leader and continues to remain so. In the Union Illinois ranks low in lime production, fifteenth in 1918.

TABLE 13—*Lime burned in Illinois, 1904-1918*

Year	Number of plants	Quantity	Value	Average price per ton
		Short tons		
1904	....	108,881	$461,068	$4.23
1905	....	98,907	421,589	4.26
1906	....	121,546	534,118	4.39
1907	22	124,784	559,305	4.48
1908	18	92,549	393,951	4.26
1909	17	104,260	454,682	4.36
1910	14	113,239	503,581	4.45
1911	16	92,169	423,762	4.60
1912	15	98,450	394,892	4.01
1913	16	95,977	433,331	4.51
1914	16	87,603	362,727	4.14
1915	14	88,604	352,954	3.98
1916	12	80,012	369,038	4.61
1917	11	83,409	501,320	6.00
1918	11	64,672	535,090	8.27

COAL

The story of coal, the last of the pre-1818 resources, mirrors the correlative development along other lines, and therefore might well receive more consideration than is possible in this chapter, especially as it is the most valuable mineral product in the State. In 1918, Illinois' 89,291,105 tons, valued at $206,860,291, were produced from 967 mines. Of these, 370 mined and shipped ninety-eight per cent of all the coal away from the vicinity of the producing mines while 597 more mined two per cent of the total production for local use. In 1918 these many mines were places of employment for 91,372 men, each of whom was responsible, on an average, for bringing to the surface almost 1,000 tons of coal during the year. In 1913, the last year unaffected by the European war, Illinois had to its credit five per cent of the world's coal production and was surpassed by but three countries in the world, one of them of course the United States itself.

The history of the growth of the coal industry is divisible into the exploration, ante-railroad, and railroad periods.

EARLY EXPLORATION

The date, 1673, which is that of the beginning of the history of Illinois coal, is the date of its discovery not only for this State but for the United States as well. In Margry's account of Joliet's voyage is found the earliest known mention:[1] "The said M. Joliet adds, that he had set down in his Journal an exact Description of the Iron-Mines they discovered, as also of the Quarries of Marble, and Cole-Pits and Places where they find Salt-Petre with several other things." One Joliet's map of 1674[2] is entered "Charbon de terre" (coal) near the present city of Utica; on Marquette's map[3] of 1681 this same "Charbon de terre" appeared; and Hennepin's map of 1689 located a "cole mine" on the Illinois above Fort Creve-Coeur (Peoria).

ANTE-RAILROAD PERIOD

The end of the early exploration period and the beginning of the ante-railroad period, may be taken as 1810, which is the year marked by the first record of shipment of coal in Illinois. Beck in "A Gazetteer of the States of Illinois and Missouri, 1823," after describing the American Bottom where the first settlement of this State was begun, says " 'Coal exists in abundance on this alluvion and the bluffs which bound it. Its first discovery was made in a very singular manner. Many years since, a tree, taking fire, communicated to its roots, which continued burning for sometime. Upon examination they were found to communicate with a bed of coal, which continued to burn until the fire was completely smothered by the falling in of a large mass of incumbent earth. The appearance of fire is still evident for a con-

---

[1]Margry, Vol. I, p. 465.

[2]Thwaites, Jesuit Relations, Vol. 19, p. 86.

[3]Thevenot, Recueil de Voyages.

siderable distance. About two miles from this place a coal bank has been opened—the vein is as thick as any at Pittsburgh.'

"It was at [this] point . . . . that the first mine was opened and we have a record of the shipment of a flatboat load of coal to New Orleans in 1810 from Brownsville [fig. 3] in Jackson County."[1]

Gazetteers of the period and journals of travelers give abundant evidence of the general recognition of the presence of coal in many parts of Illinois.[2] Just as all such references are to outcrops of coal along stream courses, so mines were located along the major streams. The list of the producing counties in 1840 shows only one that is not bordered by or does not include the Misssissippi, the Illinois, or the Wabash rivers, or their larger tributaries.

Coal production in 1840[3]

County	*Men*	*Bushels*
Adams	5	2,700
Edwards	1	2,000
Gallatin	2	1,500
Henry	2	2,250
Jackson	21	15,000
Lawrence	6	1,650
Madison	25	97,250
Marshall	3	4,000
Morgan	3	2,000
Peoria	8	12,000
Perry	1	1,500
Randolph	11	6,011
Sangamon	10	82,000
Schuyler	5	5,230
Scott	18	52,200
Shelby	2	2,700
St. Clair	24	129,396
Vermilion	..	2,800
Warren	..	2,800

The control of streams over the distribution of coal-mining operations had three phases. In the first place production began earliest along streams because there the stream's action had exposed it. It was only after deep drilling that coal was discovered away from outcrops along streams, and during the ante-railroad period enough coal could be found in the valleys so as to render the expense of exploration with the drill unnecessary and indeed almost unthought of. It is no wonder that the idea arose that Illinois coal lay "principally in the ravines and points of bluffs," as was written in Hunt's Merchants Magazine for 1841.[4]

---

[1]Andros, S. O., Coal Mining in Illinois, Ill. Coal Mining Investigations, Bull. 13, pp. 13-14, 1915.

[2]The reader will find a collection of references and quotations on which this statement is based in "Coal Mining in Illinois" on pages 14 to 34 previously referred to.

[3]U. S. Census Report, 1840.

[4]Andros, S. O., Coal Mining in Illinois, Ill. Coal Mining Investigations, Bull. 13, p. 33, 1915.

In the second place, stream valleys guided the early settlers and there population was centered.

And in the third place the streams afforded means of transportation. To transport a bulky commodity like coal economically over any great distance was well-nigh impossible except by water until the railroad era, and during all the ante-railroad period, shipping mines and their markets were confined to the vicinity of streams. It was in response to the demands of the coal industry that some of the first improvements along transportation lines were made. For example, the first macadamized road in the State, almost fourteen miles long, was built between Belleville and St. Louis, probably because of the demand for coal in St. Louis and difficulties of transportation of the product to that market over the floodplain swamps; and the first railroad in the Mississippi valley, the Coal Mine Bluffs Railroad by name, built in 1837 by Governor Reynolds between St. Louis and a coal mine on the Mississippi bluff, was for the explicit purpose of serving the industry. "Governor Reynolds says, 'I had a large tract of land located on the Mississippi Bluff, six miles from St. Louis, which contained in it inexhaustible quantities of bituminous coal. This coal mine was the nearest to St. Louis, Misssouri, of any other on this side of the Mississippi River. I had also most of the land on which a railroad might be constructed to convey the coal into market. Under these circumstances, a few others with myself, decided to construct a railroad from the bluff to the Mississippi, opposite St. Louis. This road was about six miles long, and although short, the engineer made an erroneous calculation of the cost—making the estimate less than one-half of the real cost. We all embarked in this enterprise when we knew very little about the construction of a railroad, or the capacity of the market for the use of the coal. In fact, the company had nothing but an excessive amount of energy and vigor, together with some wealth and standing, with which to construct the road; and we accomplished it. We were forced to bridge a lake over 2,000 feet across, and we drove down piles more than eighty feet into the mud and water of the lake, on which to erect the bridge. We put three piles on the top of one another, fastened the ends together, battering the piles down with a metal battering-ram of 1,400 pounds weight. The members of the company themselves hired the hands—at times one hundred a day—and overlooked the work. They built shanties to board the hands in, and procured provisions and lodgings for them. They graded the track, cut and hauled timber, piled the lake, built the road, and had it running in one season of the year 1837. This work was performed in opposition to much clamor against it, that it would not succeed, that we would break at it, and such predictions. We had not the means nor the time in one year to procure the iron for the rails, or the locomotive, so we were compelled to work the road without iron, and with horsepower. We did so, and delivered much coal to the river. It was strange how it was possible we could con-

struct the road under these circumstances. It was the first railroad built in the Mississippi valley, and such an improvement was new to every one, as well as to our company. The members of the company and I—one of them —lay out on the premises of the road day and night while the work was progressing; and I assert that it was the greatest work or enterprise ever performed in Illinois under the circumstances. But it well-nigh broke us all.' "[1]

THE RAILROAD PERIOD

Although the first railroad was built in 1837, the railroad period is not considered as beginning until 1850, which is the year when railroad mileage began to increase rapidly (fig. 5). Perhaps an even later date might well be taken for it was not until after 1850 that locomotives first began to use coal instead of wood as fuel. "Until 1854, coal was hauled by wood-burning locomotives and the greatest impetus given to expansion of the coal industry after the construction of railroads was the purchase by the Galena and Chicago Union Railroad in that year of five locomotives 'guaranteed to burn bituminous coal mined in Illinois.' "[2]

All through the Civil War period of the State's history and the following period of industrial growth (1848-1893), it was essentially a case of development of mines where railroads were built, but after that time, as the graph (fig. 5) clearly shows, railroads were no longer the dominant factor in the situation; from that time on the rate of increase of main-track mileage decreased from year to year, while that of coal tonnage increased by leaps and bounds.

An additional basic factor in the great increase in coal production in the latter half of the railroad period was the impetus given to steel production by the establishment in 1870 of the Bessemer process of steel manufacture. Though the chemical quality of Illinois coal does not permit its use as blast furnace fuel, the iron and steel industry has played a leading part in the huge increase of coal production in the past twenty-five years, for coal enters into almost every phase of manufacture and industry that depends for existence on steel, which means that, to a large degree, the coal industry grows in proportion to the growth of aggregate manufactures and is conditioned by the steel industry.

The great increase of population, the enormous growth of manufactures, the improvements in transportation facilities, the increase in wealth, and even the rise in standards of living, are all so dependent upon the iron and steel industry that the abundance of iron is commonly taken as a measure of national wealth. But, as J. Russell Smith says: "Coal is the twin of iron in the production of the new world commerce, because this commerce is carried in vehicles made chiefly of iron, driven by power derived from coal.

[1]From a History of St. Clair County by MacDonough as quoted in Coal Mining in Illinois, Illinois Coal Mining Investigations, Bull. 13, pp. 21-22, 1915.

[2]Ibid., p. 28.

Coal also furnishes heat for the reduction of iron, and power for driving the machinery employed in its manufacture."[1] And so the abundance of coal must be regarded as a second measure of the wealth of a people, coördinate with iron. Indeed, though the two are interdependent in the present scheme of industrial economy and therefore are of equal importance, coal is perhaps even better entitled to be the final measure of wealth in any area: witness the manufacture of Lake Superior iron ores in distant eastern coal field centers like Pittsburgh, and the smelting of Missouri lead and zinc in cities of the Illinois coal fields.

The iron and coal industries of today have many points of similarity: both are developed only where manufacturing is well advanced, both require good transportation facilities, and both are fundamental to good transportation. Both require many laborers and large markets such as only concentrated population can give, and both may be regarded as industrial barometers. As true for coal as for iron is Smith's statement that "it very distinctly is *not* a frontier industry."[2] Thus there is to be read from the rising curve of coal production (fig. 5) not only the rise of coal mining itself but, more important, the advance of Illinois from the frontier stage of fifty years ago to its present high rank in modern industrial civilization.

There has been little change in the number of coal producing counties for thirty-five years or more, but the counties have not maintained a corresponding constancy of rank in coal production.

Five counties—St. Clair, Sangamon, Madison, Macoupin, and Vermilion—appear among the ten leading counties every year since 1880, their continued prominence resulting from great abundance and a sufficiently good quality to enable them to hold their positions year after year. Comparing the years 1880 and 1918, the other five are in no instance identical, La Salle, Will, Fulton, Peoria, and Rock Island counties completing the list of ten for 1880, and Franklin, Williamson, Saline, Montgomery, and Christian counties completing that for 1918. Those of the 1880 list are all Illinois or Mississippi river counties and owe their early start and prominence as much to their location, which is favorable to transportation, as to the abundance or good quality of their coal. Conversely, the fact that none of the five new counties of the 1918 list is on an important river shows the modern release of coal production from the early restrictions imposed upon it by lack of railroads; it also gives evidence of the new scientific methods of search, such as efficient methods of test drilling, mine planning, and managing under the supervision of geologists and engineers as contrasted with the early practice of drifting into a valley bluff wherever an outcrop presented itself. The rise of Franklin and Williamson counties to first and second place, respectively, in 1918, from no production at all in 1900 for the former

[1]Smith, Commerce and Industry, p. 139.
[2]Ibid., p. 146.

FIG. 5. Increase in main track railroad mileage and quantity of coal produced in Illinois, 1833-1918.

TABLE 14.—*Production of coal in Illinois,*

County	1905	1906	1907	1908	1909	1910	1911
Bond	126,231	132,325	138,990	60,129	89,861	139,398	119,258
Bureau	1,701,255	1,580,085	2,010,762	1,512,971	1,612,452	973,346	1,628,680
Calhoun	4,727	5,045	2,850	3,521	....	....	1,400
Christian	879,360	934,452	1,368,159	1,377,166	1,395,158	1,223,295	1,222.259
Clinton	579,281	515,796	1,302,391	1,078,848	970,709	950,243	921,225
Franklin	....	....	1,306,966	2,187,383	2,316,509	1,778,768	3,555,586
Fulton	1,529,249	1,579,224	2,113,643	2,012,415	2,388,617	1,721,527	2,133,029
Gallatin	82,682	92,731	78,055	59,667	64,713	70,091	63,008
Greene	4,435	2,206	2,310	9,506	7,318	9,082	6,207
Grundy	1,310,892	1,162,019	1,327,321	1,081,442	1,114,101	600,281	776.800
Hamilton	....	....	....	(*c*)	....	....	....
Hancock	3,300	4,498	2,034	1,406	1,085	640	230
Henry	146,995	149,188	149,721	141,624	137,060	124,243	90,722
Jackson	818,841	646,196	645,333	624,055	652,280	584,240	687,753
Jefferson	25,925	7,600	12,000	18,675	4,800	10,000	9,500
Jersey	....	1,397	1,162	1,496	1,000	....	....
Kankakee	700	39,499	26,704	30,994	25,000	....	....
Knox	58,972	51,654	40,996	41,040	21,973	28,295	30,136
La Salle	1,772,988	1,467,672	1,677,990	1,557,173	1,686,391	1,178,885	1,610,470
Livingston	284,984	273,831	303,497	265,666	246,031	162,898	89,423
Logan	445,546	435,559	477,115	372,980	395,888	409,244	334,860
McDonough	19,496	43,774	32,199	17,818	16,276	26,338	8,027
McLean	159,921	145,000	151,146	95,854	116,412	83,982	96,517
Macon	231,235	292,884	269,766	235,237	238,607	235,361	236,203
Macoupin	3,177,484	3,637,827	4,507,270	3,894,199	4,597,775	3,854,229	4,688,212
Madison	3,434,399	3,324,857	3,927,721	3,367,820	3,373,798	4,102,773	3,152,705
Marion	1,009,759	1,042,866	1,185,533	981,284	1,171,950	812,873	1,224,326
Marshall	499,672	418,904	482,796	393,281	295,812	267,447	423,984
Menard	415,266	429,971	389,918	355,309	303,948	332,557	190,477
Mercer	532,854	412,165	453,621	376,435	369,762	229,024	297,552
Montgomery	598,064	720,415	1,289,021	1,410,978	1,780,668	1,799,720	2,395,814
Morgan	4,565	9,100	5,513	3,244	1,200	1,300	1,268
Moultrie	....	....	....	(*d*)	(*f*)	....	....
Peoria	897,946	914,863	1,103,312	921,929	914,961	810,595	1,037,362
Perry	1,298,572	1,509,716	1,784,469	1,576,891	1,423,135	1,367,771	1,272,292
Putnam	....	156 928	362,858	466,019	597,703	364,882	772,976
Randolph	440,991	634,270	824,761	751,605	799,893	1,025,557	777,746
Rock Island	68,383	62,321	52,938	50,781	46,228	66,207	65,983
St. Clair	3,329,914	4,904,811	4,511,879	3,696,017	3,471,630	5,788,567	3,931,479
Saline	675,701	980,864	2,247,842	2,552,137	3,283,939	2,459,650	3,820,410
Sangamon	4,324,263	4,543,849	5,160,042	5,015,608	5,616,357	4,449,634	5,137,835
Schuyler	2,880	3,090	7,553	15,269	4,573	2,427	6,138
Scott	13,423	12 437	17,639	3,427	2,056	2,400	464
Shelby	104,216	138,257	155,930	181,373	124,087	135,672	81,615
Stark	22,725	17,661	25,897	20,351	23,159	32,582	37,293
Tazewell	231,373	189,882	235,971	206,882	208,049	155,659	220,783
Vermilion	2,342,238	2,389,285	2,973,253	2,452,485	1,919,955	2,515,250	3,385,200
Warren	10,354	9,520	9,139	11,687	12,304	10,275	9,044
Washington	85,913	85,812	29,000	72,500	31,322	22,500	25,000
White	....	8.000	16,453	19,583	22,133	23,722	35,681
Will	137,957	154,955	183.985	162,239	162,307	124,652	178,397
Williamson	4,167,952	4,417,987	5,697,944	5,670,474	6,537,654	4.620,372	6,614,029
Woodford	*a*348,707	*a*717,566	*b*158,742	*e*174,031	194,410	125,823	164,001
Small mines	69.777	69,299	75,036	68,786	*g*111,981	85,969	109,759
Total	38,434,363	41,480,104	51,317,146	47,659,690	50,904,990	45,900,246	53,679,118
Total value	$40,577,592	$44,763,062	$54,687,382	$49,978,247	$53,522,014	$52,405,897	$59,519,478

a Includes production of Franklin County.
b Includes production of Wabash County.
c Included with production of Hancock County.
d Included with production of Woodford County.
e Includes production of Edgar and Moultrie counties.
f Included with production of small mines.

by counties, in short tons, 1905-1918

1912	1913	1914	1915	1916	1917	1918	County
232,571	223,786	123,730	27,659	86,805	(*d*)	(*d*)	..............Bond
1,677,317	1,639,208	1,284,311	1,202,698	1,340,018	1,363,362	1,181,197	.............Bureau
1,156	....	....	....	....	....	....	............Calhoun
1,467,846	1,504,716	1,486,053	2,135,052	2,516,336	3,133,360	3,340,377	...........Christian
1,040,479	1,049,575	1,090,787	1,315,648	1,307,712	1,464,722	1,533,702	............Clinton
4,442,284	6,072,102	7,311.209	8,027,773	9,388,292	11,455,238	12,373,356	...........Franklin
2,453,424	2,388,775	2,052,170	1,849,906	2,109,950	2,820,495	2,552,105	.............Fulton
64,244	46,105	81,735	77,380	66,933	73,489	226,544	...........Gallatin
7,841	5,009	6,665	5,764	2,963	(*d*)	(*d*)	.............Greene
540,787	401,527	388,368	293,660	324,794	418,033	317,801	............Grundy
....	....	....	....	....	....	....	...........Hamilton
....	....	1,678	1,285	2,656	(*d*)	(*d*)	...........Hancock
58,613	43,383	47,010	46,219	44,502	50,032	41,332	..............Henry
703,190	723,863	601,697	682,042	772,788	807,160	1,055,225	............Jackson
21,032	35,000	9,051	8,900	....	....	....	...........Jefferson
....	....	....	....	....	....	....	..............Jersey
....	....	....	....	....	....	....	..........Kankakee
22,293	18,280	14,150	11,985	9,897	14,050	7,669	...............Knox
1,537,591	1,564,459	1,279,592	1,192,794	1,050,900	1,151,156	1,083,879	............La Salle
65,774	63,877	64,461	63,341	110,709	125,363	105,341	.........Livingston
466,528	351,666	352,181	311,346	465,159	599,744	(*d*)	..............Logan
14,446	12,603	5,251	5,132	13,927	(*d*)	(*d*)	........McDonough
89,781	88,777	79,008	80,321	77,755	(*d*)	(*d*)	............McLean
291,590	206,140	217,217	162,550	189,529	308,053	347,400	.............Macon
4.986.574	5,097.619	4,555,834	4,832,540	5,492,216	7,070,146	7,381,165	..........Macoupin
4,025,878	3,732,153	3,546,256	3,419,955	4,173,587	5,364,251	5,074,383	...........Madison
1,311,024	988,964	906,837	925,365	999,109	1,120,426	1,119,206	.............Marion
449,660	426,490	383,331	408,566	438,983	437,087	310,784	...........Marshall
177,578	120,174	76,603	78,893	159.336	213,478	481,813	............Menard
393,018	408,875	372,528	340,840	274,692	268,791	287,443	.............Mercer
2,182,823	2,689,702	2,597,677	2,877,459	3,075.712	4,204,722	4,231,122	........Montgomery
1,000	1,222	*j* 906	300	....	....	....	............Morgan
....	(*d*)	....	....	207,044	(*d*)	(*d*)	...........Moultrie
1,225,574	1,163,073	1,055,323	1,193,351	1,307,900	1,547,916	1,295,460	.............Peoria
1,444,114	2,013,128	2,236,480	2,383,658	2,474,573	2,739,914	2,917,590	..............Perry
720,048	724,170	605,863	636,776	661,570	(*d*)	(*d*)	............Putnam
798,163	763,472	956,582	892,948	965,089	1,397,629	1,627,414	..........Randolph
66,817	35,672	36,022	24,747	33,580	55,082	36,068	........Rock Island
4,734,840	4,383,459	3,246,322	2,908,129	4,172,697	6,955,766	7,810,186	............St. Clair
4,417,874	4,189,003	3,746,656	4,166,249	4,153,516	5,188,777	5,684,594	..............Saline
5,714,742	5,875,853	5,679,595	5,075,823	5,128,970	8,062,735	8,331,764	..........Sangamon
4,573	1,855	2,781	5,864	8,115	8,006	7,004	...........Schuyler
460	600	1,000	1,000	1,000	(*d*)	(*d*)	..............Scott
185,501	193,632	196,339	88,672	78,273	132,591	193,346	.............Shelby
34,176	14,610	12,703	11,919	8,013	(*d*)	(*d*)	..............Stark
271,321	341,626	335,566	263,247	385,611	508,215	484,681	...........Tazewell
3,434,923	3,501,880	2,394,081	2,469,263	2,833,909	3,886,480	3,973,478	.... Vermilion
5,021	3,383	1 510	1,339	4,490	(*d*)	(*d*)	............Warren
244,879	319,370	497,000	445,028	694,468	812,563	821,357	........Washington
27,052	22,304	32,111	32,118	46,114	(*d*)	(*d*)	...............White
130,806	149,926	136,758	141,416	80,885	(*d*)	(*d*)	................Will
7,354,507	7,644,397	7,066,029	7,264,395	8,077,627	10,645,697	11,338,562	.........Williamson
185,499	*h* 302,184	*h* 315,840	*h* 337,514	*j* 192,045	*k* 3,617,222	*l* 1,996,093	..........Woodford
157,994	71,097	98,340	100,747	103,587	134,820	73,438	........Small mines
59,885,226	61,618,744	57,589,197	58,829,576	66,195,336	86,199,387	89,291,105	...........Total
$70,294,338	$70,313,605	$64,693,529	$64,622,471	$75,566,086	$162,281,822	$206,860,291	.......Total value

g Includes production of Crawford and Moultrie counties.
h Includes production of Moultrie County.
i Included with production of Morgan County.
j Includes production of Johnson County.
k Includes Bond, Greene, Hancock, Johnson, McDonough, McLean, Moultrie, Putnam, Scott Stark, Warren, White, Will and Woodford counties.
l Includes same counties listed in (*k*) with the addition of Logan County.

and ninth place for the latter, is a particularly good example of the effect of modern methods in an old industry.

Another sign of increasing efficiency is seen in the decrease in the total number of mines during the last decade. The number of mines fell from a maximum of 1,018 mines of all types in 1906 to 810 in 1917 and 967 in 1918, while at the same time the total production doubled. Both local and shipping mines have decreased in number and increased in tonnage, the greater increase for the latter class probably depending upon the fact that the shipping mines are also the larger mines worked by the better organized and capitalized companies.

Comparisons drawn on the basis of the relations between number of men and production are less simple. For the period from 1893 to 1918 more rapid *relative* increase in efficiency is indicated for local mines than for shipping mines by these data, but the per capita production for the former is actually still far below that for latter and shows the efficiency of shipping mines to be actually greater throughout the period. The fact remains, however, that the gap between shipping and local mines in this regard is slowly narrowing.

One factor in producing such a result may be that the hindrance imposed by excessive competition upon efficient operation is felt more by shipping mines than by local mines.[1]

The idea that competition must force efficiency is so generally accepted, so almost axiomatic, that the failure of the principle in this instance requires an explanation. The remarkable development of coal-carrying railroads and the low ton-mile rates made for long hauls have permitted the more cheaply produced eastern coals to move into Illinois and set prices that are too low to permit efficient development. The ease of opening new mines causes scores of them to spring up with every period of unusual prosperity, and with the slack spring and summer seasons or with the return of normal or subnormal prosperity the effort of each of the many operators to keep his own mine going even at a slight loss results in excessive and unfair competition. Proper organization or consolidation could of course partly remedy such difficulties, but to a certain extent they are unavoidable, as Illinois coal stocks very poorly and therefore labor rates must be high to cover the consequent period of summer idleness even though mines be reduced to a number conducive to efficiency. All these conditions have led to a steady decline in the margin of profit, a feature that is injurious to the interests of both producer and consumer when it is carried too far.[2]

---

[1]Rice, "Mining Wastes and Mining Costs in Illinois," in Ill. State Geol. Sur. Bull. 14, p. 212 ff.

[2]Andros, Coal Mining in Illinois, Coal Mining Investigations, Bull. 13, figure 67, p. 221.

Fig. 6. Old scoop, rake and hammer from a primitive Illinois coal mine.

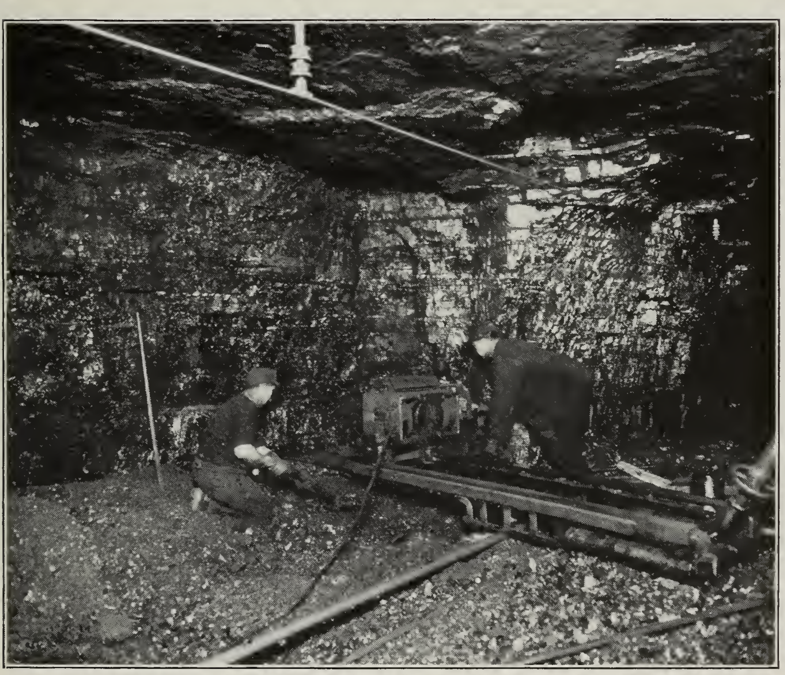


Fig. 7. A modern machine for mining coal.

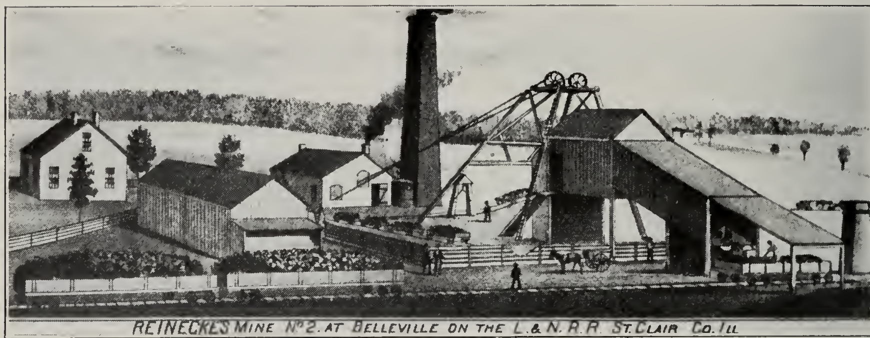


FIG. 8. A surface plant of the early railroad period.

In spite of the hindrance of excessive competition, there are numerous examples of increasing efficiency in the coal industry of Illinois. Since 1900 there has been a notable increase in the number of mines using machines, and in the number of machines in use in each mine. This has resulted in a fourfold increase in tonnage for mines so equipped as compared with a twofold increase for all other mines during the past seventeen years. The contrasts brought out by figures 6 and 7, and figures 8 and 9, typify the advances made in coal-mining practice since the early days.

FIG. 9. A modern fireproof steel tipple.

Again, in protection of miners against injury and loss of life the coal mining industry shows some improvement. The actual increase in non-fatal accidents and in the number of lives lost is not great, but in the number of tons of coal produced to each life lost a measure of the progress is had. For, whereas in the unfortunate year of 1883 only 90,000 tons of coal were taken out for each life lost, and whereas the average tonnage per life lost during the entire period from 1883 to 1918 was 275,894 tons, in 1918 for each man lost, 354,250 tons were recovered.

CONDITION OF THE COAL INDUSTRY IN 1917 AND 1918

For the year 1918 the statistical information available on production, distribution, consumption, and prices of coal is more detailed and more abundant than ever before. This is the case because the statistical forces of the U. S. Geological Survey were vastly augmented by coalition with those of the Fuel Administration, and the two organizations worked together most effectively in gathering information needed for the working out of the war-time fuel problems. The following paragraphs are a combination of quotations taken from the Mineral Resources volume of the U. S. Geological Survey for 1918, where summaries and interpretations of these statistics are given.

TABLE 15.—*Coal produced in Illinois, by counties, in 1917*

County	Loaded at mines for shipment	Sold to local trade and used by employees	Used at mines for steam and heat	Total quantity	Total value	Average value per ton	Average number of days worked	Average number of employees
	Tons	*Tons*	*Tons*	*Tons*				
Bond and White....	263,085	17,624	11,194	291,903	$ 570,777	$1.96	233	253
Bureau............	1,237,589	75,004	50,769	1,363,362	3,264,762	2.39	285	2,629
Christian...........	2,939,888	128,035	65,437	3,133,360	5,033,909	1.61	242	2,852
Clinton............	1,315,869	87,209	61,644	1,464,722	2,478,142	1.69	203	1,568
Franklin...........	11,055,327	93,112	306,799	11,455,238	24,826,209	2.17	217	10,483
Fulton.............	2,607,467	114,893	98,135	2,820,495	5,842,466	2.07	202	3,199
Gallatin and Johnson	64,828	7,225	2,684	74,737	162,702	2.18	227	100
Greene, McDonough, Moultrie, and Stark	237,737	19,768	10,501	268,006	525,841	1.96	243	252
Grundy............	382,042	18,230	17,761	418,033	1,136,872	2.72	267	721
Hancock, Scott, and Warren.........	....	9,410	....	9,410	27,316	2.90	207	29
Henry.............	....	47,911	2,121	50,032	122,040	2.44	259	92
Jackson............	693,341	86,445	27,374	807,160	1,677,391	2.08	205	1,001
Knox..............	75	13,125	850	14,050	33,463	2.38	212	25
La Salle............	768,300	174,494	208,362	1,151,156	2,824,317	2.45	273	1,515
Livingston..........	40,557	79,772	5,034	125,363	302,158	2.41	263	169
Logan.............	470,395	99,430	29,919	599,744	1,245,360	2.08	257	738
McLean, Putnam, Will, and Woodward	915,653	121,075	52,689	1,089,417	2,324,545	2.13	282	1,831
Macon.............	103,745	186,136	18,172	308,053	808,345	2.62	252	541
Macoupin..........	6,768,331	142,243	159,572	7,070,146	11,268,463	1.59	248	6,135
Madison...........	5,080,675	163,982	119,594	5,364,251	8,867,527	1.65	248	4,424
Marion.............	1,078,087	20,415	21,924	1,120,426	2,359,699	2.11	227	1,126
Marshall...........	315,889	95,978	25,220	437,087	1,134,268	2.60	297	809
Menard............	163,066	44,731	5,681	213,478	423,201	1.98	257	246
Mercer.............	231,119	21,496	16,176	268,791	559,400	2.08	235	364
Montgomery	4,098,210	43,106	63,406	4,204,722	7,974,031	1.90	238	3,664
Peoria..............	1,392,783	132,120	23,013	1,547,916	3,026,966	1.96	283	1,667
Perry..............	2,567,623	104,232	68,059	2,739,914	5,209,006	1.90	205	2,857
Randolph..........	1,335,249	25,771	36,609	1,397,629	2,361,474	1.69	224	1,334
Rock Island........	....	53,593	1,489	55,082	114,252	2.07	205	61
St. Clair...........	6,399,749	330,588	225,429	6,955,766	11,951,313	1.72	225	6,278
Saline..............	5,027,201	48,330	113,246	5,188,777	9,337,641	1.80	238	5,460
Sangamon..........	7,555,314	346,029	161,392	8,062,735	13,768,705	1.71	264	7,316
Schuyler...........	....	8,060	....	8,060	16,610	2.06	167	19
Shelby.............	101,873	22,018	8,700	132,591	313,790	2.37	177	235
Tazewell...........	414,906	85,071	8,238	508,215	1,024,281	2.02	273	566
Vermilion..........	3,631,877	207,241	47,362	3,886,480	7,069,877	1.82	277	3,554
Washington........	736,874	51,664	24,025	812,563	1,500,612	1.85	277	707
Williamson.........	10,288,621	81,406	275,670	10,645,697	20,493,024	1.93	231	9,270
Small Mines........	....	134,820	....	134,820	301,067	2.23	....	....
	80,283,345	3,541,792	2,374,250	86,199,387	162,281,822	1.88	243	84,090

TABLE 16.—*Coal produced in Illinois, by counties, in short tons, in 1918*

County	Loaded at mines shipment	Sold to local trade and used by employees	Used at mines for steam and heat	Total quantity	Total value	Average value per ton	Average number of days worked	Average number of employees
	Tons	*Tons*	*Tons*	*Tons*				
Bond and White....	341,921	23,858	15,090	380,869	$ 867,830	$2.28	245	379
Bureau..........	1,057,949	73,725	49,523	1,181,197	3,634,242	3.08	276	1,999
Christian..........	3,130,120	139,566	70,691	3,340,377	6,779,546	2.03	228	2,877
Clinton..........	1,395,797	86,954	50,951	1,533,702	3,388,733	2.21	210	1,533
Franklin..........	11,880,427	123,300	369,629	12,373,356	29,224,580	2.36	220	11,218
Fulton..........	2,390,519	82,796	78,790	2,552,105	6,662,120	2.61	240	3,066
Gallatin and Johnson	207,793	10,441	9,210	227,444	494,951	2.18	221	252
Greene, McDonough, Moultrie and Stark	200,581	15,751	11,905	228,237	500,684	2.19	237	226
Grundy..........	285,929	15,381	16,491	317,801	1,041,057	3.28	235	457
Hancock, Scott and Warren..........	....	2,913	....	2,913	10,732	3.68	152	11
Henry..........	....	39,637	1,695	41,332	120,237	2.91	292	76
Jackson..........	886,901	129,895	38,429	1,055,225	2,624,528	2.49	227	1,206
Knox..........	....	6,869	800	7,669	20,069	2.62	193	25
La Salle..........	706,078	331,750	46,051	1,083,879	3,298,978	3.04	271	1,691
Livingston..........	25,792	74,473	5,076	105,341	362,763	3.44	236	162
Logan, McLean, Putnam, Will and Woodford..........	1,002,245	235,896	71,595	1,309,736	3,398,260	2.59	268	2,044
Macon..........	118,752	209,371	19,277	347,400	992,609	2.86	266	455
Macoupin..........	7,130,626	81,874	168,665	7,381,165	15,917,126	2.16	244	6,533
Madison..........	4,820,571	136,081	117,731	5,074,383	11,532,446	2.27	229	4,377
Marion..........	1,061,749	21,932	35,525	1,119,206	2,560,888	2.29	265	975
Marshall..........	222,627	62,731	25,426	310,784	1,322,028	4.25	267	669
Menard..........	158,508	39,480	5,489	203,477	481,813	2.37	265	217
Mercer..........	257,713	14,597	15,133	287,443	808,392	2.81	183	354
Montgomery..........	4,099,379	53,518	78,225	4,231,122	9,748,693	2.30	218	3,824
Peoria..........	1,148,236	126,665	20,559	1,295,460	3,379,552	2.61	247	1,493
Perry..........	2,683,943	128,467	105,180	2,917,590	6,525,306	2.24	225	2,776
Randolph..........	1,548,088	38,689	40,637	1,627,414	3,547,510	2.18	233	1,518
Rock Island..........	....	34,723	1,345	36,068	81,078	2.25	205	50
St. Clair..........	7,266,076	311,998	232,112	7,810,186	16,607,837	2.13	231	7,047
Saline..........	5,454,661	74,353	115,580	5,684,594	13,478,859	2.37	251	5,782
Sangamon..........	7,809,564	367,432	154,768	8,331,764	18,426,528	2.21	250	7,595
Schuyler..........	150	6,854	....	7,004	15,198	2.17	283	14
Shelby..........	158,636	24,086	10,624	193,346	525,551	2.72	207	272
Tazewell..........	418,292	60,392	5,997	484,681	1,268,769	2.62	235	574
Vermilion..........	3,709,974	215,812	47,692	3,973,478	9,017,278	2.27	261	3,434
Washington..........	716,138	79,222	25,997	821,357	1,857,741	2.26	272	574
Williamson..........	10,973,129	86,124	279,309	11,338,562	26,138,979	2.31	230	10,210
Small Mines..........	....	73,438	....	73,438	196,800	2.68	....	....
	83,268,864	3,641,044	2,381,197	89,291,105	206,860,291	$2.32	238	85,965

PRODUCTION

The dominating factor in the coal industry in 1918 was the control over every feature, from production to consumption, exercised by the Fuel Administration. The chaotic conditions that marked the closing months of 1917 continued through the first two months of 1918, for the situation was so bad that no hope was entertained of getting the distribution of coal into orderly shape until the effects of the extreme weather had passed and the organization of the Fuel Administration had progressed to the point of enabling it to assume full control. Much of the criticism that has been leveled at the Fuel Administration is based on the happenings of the winter of 1917-18, when no hand could stay the fury of the elements and when sufficient time had not elapsed from the inception of Government control to furnish an adequate organization to handle the situation.

Contrasted with the uncertainty and disturbance in 1917 and the first months of 1918 was the definiteness of purpose and of control that existed once the Fuel Administration had become organized and its policies had become formulated and were appreciated by the industry and the public. The definite and positive control of distribution by the Fuel Administration began on April 1, 1918, with the installation of the zone system and the allotment of coal under the budget system. By the first of July it was apparent to those closely in touch with conditions that, barring unforeseen contingencies, the country would be fueled for the year, and by the first of October there was no doubt as to the outcome. In fact by October the problem in certain areas was not to find coal to meet the demand, but to find consumers to take the coal that was being produced. After the signing of the armistice, November 11, the demand for coal appreciably slackened, because of the cessation of war industry, and by the end of the year the lack of market was an important factor with many bituminous coal districts and mines operating on part time.

There was no coal shortage in 1918; sufficient coal, both anthracite and bituminous, was produced to care fully for all needs, and there can be no doubt that, even had the war continued, the country would not have suffered from lack of fuel. The mildness of the winter of 1918-19 of course entailed a decrease in the requirements, particularly of anthracite for house use.

A new high record for production of coal in Illinois was established in 1918 by an output of 89,291,105 tons, an increase over the previous high record of 1917 of 3,091,718 tons, or 3.6 per cent. By far the greater part of this increase came from the three southern counties, Franklin, Williamson, and Saline, in which is produced the highest-grade coal in Illinois. The central or Springfield district also had an increase, as did the Belleville and Danville districts, but the northern and Fulton-Peoria districts recorded decreases. The proportionately large increase obtained in the southern field was made possible by the developments in the last few years and because

of the need and demand for the excellent coal from this field to fill the requirements of consumers who were denied the higher grades of eastern coal by the zoning system. The following table shows in a general way the relative progress of the principal producing districts in Illinois from 1916 to 1918. As the totals given were arrived at by combining county totals and not all the counties in the State are included and because the fields described are not actually defined by county lines, the following record must be considered as relative rather than as representing the actual production in these well-known trade and rate districts.

TABLE 17.—*Production of coal in Illinois, by groups of principal counties, 1916 to 1918*

Field	County	1916	1917	1918
Northern......	Grundy, Will, LaSalle, Bureau and Putnam..............	3,458,000	3,738,000	3,215,000
Danville.......	Vermilion....................	2,834,000	3,886,000	3,973,000
Fulton-Peoria..	Tazewell, Rock Island, Fulton, and Knox.................	4,203,000	5,215,000	4,663,000
Central........	Logan, Macon, Christian, Montgomery, Menard, Moultrie, Macoupin, and Sangamon...	17,234,000	23,848,000	24,519,000
Belleville......	Madison, Bond, St. Clair, Monroe, Randolph, Perry, Marion, and Jefferson..........	12,872,000	17,716,000	18,758,000
Southern......	Franklin, Williamson, Saline, and Gallatin..............	21,686,000	27,363,000	29,623,000

The average number of days worked decreased from 243 in 1917 to 238 in 1918 and the number of men increased slightly from 84,090 to 85,965. The average daily output per man, however, increased from 4.22 tons in 1917 to 4.37 tons in 1918, and by reason of the greater effectiveness of the labor the total production for the State was increased. Had not the demand fallen off in the last quarter of the year an even larger production would have been attained.

The weekly statistics of operation, shown graphically in figure 10, indicate that largely because of lack of cars the mines in Illinois averaged only about 70 per cent of full running time in the first five months of 1918, and that from June to the end of October the average was increased to nearly 80 per cent. Because of no market, mainly lack of demand for steam coal, which affected the central and neighboring fields, the production declined in November and December to less than 60 per cent.

DISTRIBUTION AND CONSUMPTION

The production of coal in Illinois increased in 1918, compared with 1917, by more than 3,000,000 tons. For consumers in the State of Illinois,

deliveries were greater in 1918 by about 5,700,000 tons; total commercial shipments to other states were about the same in the two years, but deliveries to railroads were more than 3,000,000 tons less in 1918 than in 1917. A considerable portion of the coal in commercial shipments from Illinois normally goes to retail dealers, and in September and October that trade represented nearly half of the total.

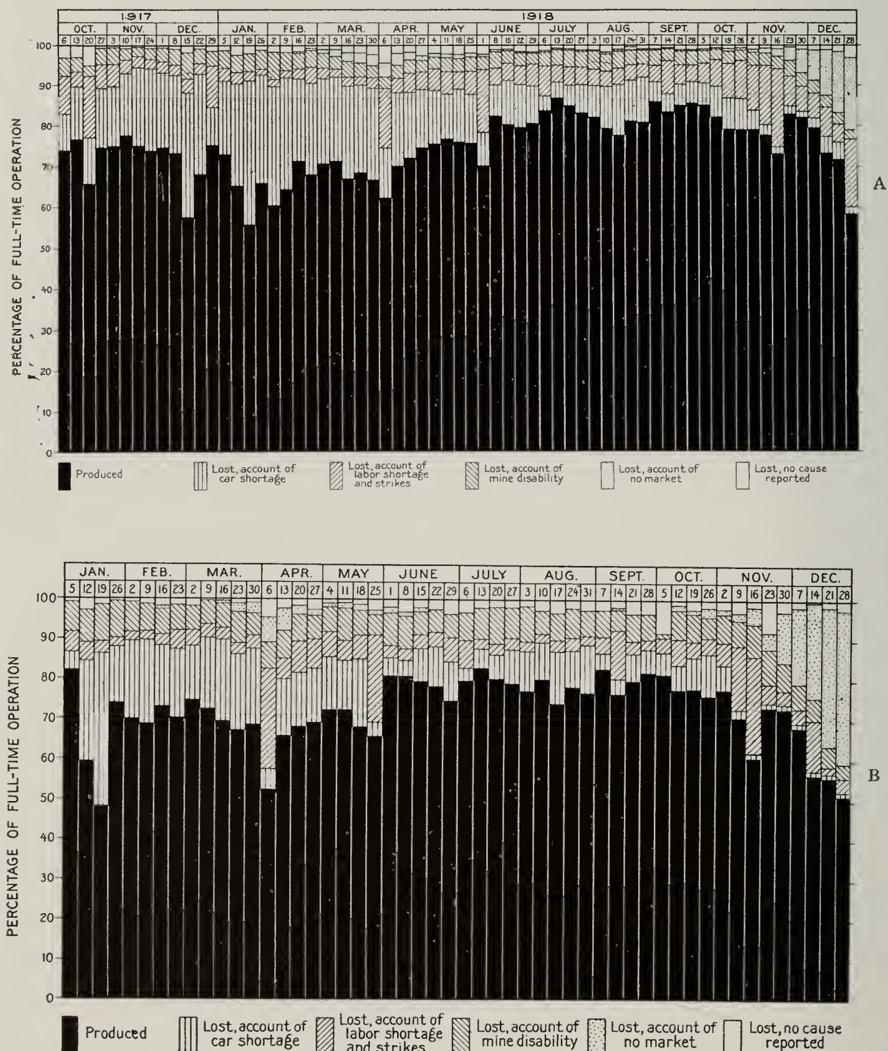


FIG. 10. Percentage of full-time operation of coal mines and of lossses of running time, by causes, and by weeks, in 1918: A, in the United States; B, in Illinois.

TABLE 18.—*Statistics of distribution and of consumption of coal for Illinois in 1917 and 1918*

	Quantity in Tons		Percentage of Total	
	1917	1918	1917	1918
Destination of coal produced in Illinois in 1917 and 1918				
Used in Illinois:				
Sold to local trade, not shipped	3,541,792	3,641,044		
Used at mines for steam and heat	2,374,250	2,381,197		
Shipped to Illinois points	25,780,675	31,405,464		
	31,696,717	37,427,705	36.7	41.9
Shipped to other States:				
Alabama	....	20,719		
Arkansas	96,000	267,628		
Indiana	2,255,000	2,410,432		
Iowa	4,026,000	3,597,048		
Kansas	107,000	46,767		
Kentucky	18,000	14,306		
Louisiana	102,000	86,112		
Michigan	706,000	983,572		
Minnesota	1,801,000	1,967,926		
Mississippi	55,000	22,954		
Missouri	6,806,000	6,830,419		
Nebraska	661,000	185,946		
North Dakota	43,000	7,820		
Ohio	63,000	16,000		
South Dakota	231,000	228,160		
Tennessee	50,000	210,128		
Texas	63,000	322		
Wisconisn	1,936,000	2,486,254		
	19,019,000	19,382,513	22.1	21.7
Delivered to railroads by all-rail routes	35,431,220	32,370,362	41.1	36.3
Exported by rail	50,000	95,125	.1	.1
Shipped to tidewater	2,450	15,400	....	....
Total production of coal in Illinois	86,199,387	89,291,105	100.0	100.0
Source of coal consumed in Illinois in 1917 and 1918				
Illinois	31,696,717	37,427,705	73.9	80.2
Shipped in from other States:				
Arkansas	20,000	29,810		
Indiana	5,165,000	6,015,607		
Iowa	....	1,703		
Kansas	....	46		
Kentucky:				
Northeastern	428,000	241,407		
Southeastern	228,000	353,095		
Western	447,000	105,638		
Hazard	25,000	40,596		
Ohio:				
Northern	25,000	9,450		
Southern	65,000	26,272		
Oklahoma	....	750		
Pennsylvania:				
Central	52,000	38,088		
Connelsville	....	3,944		
Pittsburgh and Panhandle of West Virginia	55,000	2.955		
Somerset and Cumberland-Piedmont	15,000	10,541		
Tennessee	45,000	....		
Virginia, southwestern	74,000	10,308		
West Virginia:				
Fairmont	30,000	2,915		
Kanawha and Kenova-Thacker	543,000	392,301		
New River	275,000	10,895		
Pocahontas and Tug River	2,650,000	969,081		
Received at Lake docks	1,050,221	960,000		
	11,192,221	9,225,402	26.1	19.8
Imports	9,520	13,664	....	....
Total consumption of coal in Illinois	42,898,458	46,666,771	100.0	100.0

Table 18 which summarizes the statistics of distribution and consumption of coal in Illinois in 1917 and 1918 is deserving of careful study. Among other things should be noted that in 1918 as compared with 1917 a greater percentage of the Illinois production was used within the State, and that a smaller percentage of the total State consumption came from the more distant sources. These two facts indicate the success of the zoning plan and other shipping regulations of the Fuel Administration, made in its attempt to eliminate unnecessarily long hauls of fuel wherever possible. Another fact brought out is that Illinois produces roughly twice as much coal as it consumes.

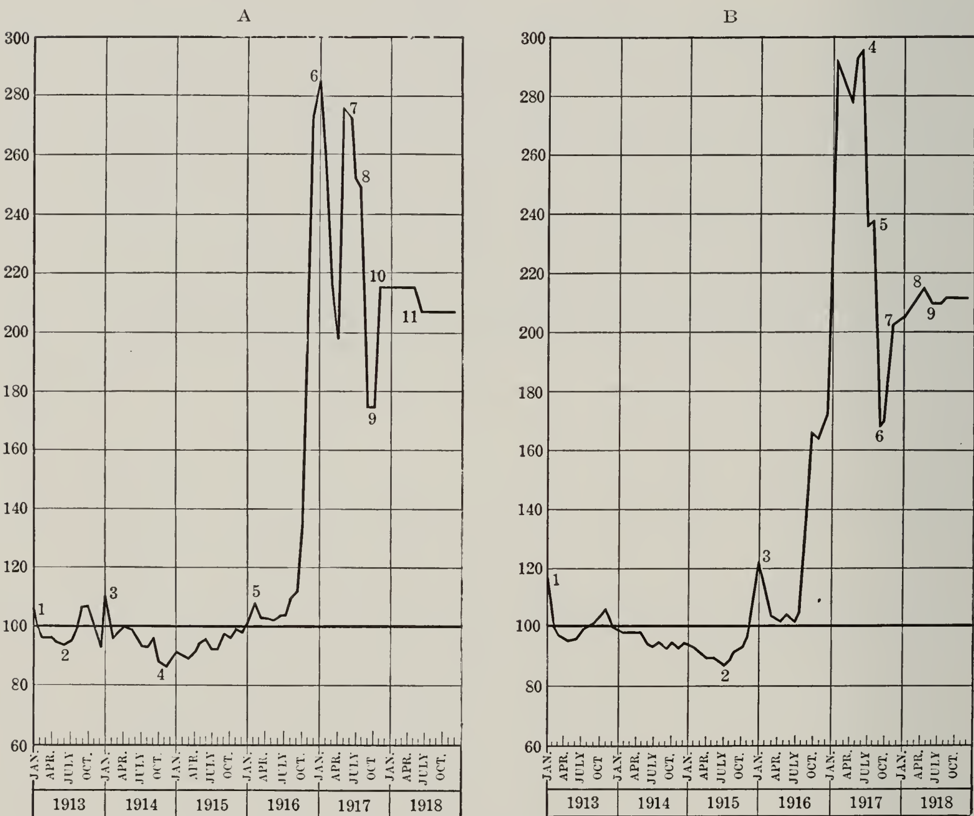


FIG. 11. Relative spot prices of all bituminous coal produced, by months, 1913-1918: A, in Illinois; B, in the United States.

PRICES

Figure 11 has been prepared to show the fluctuations in the prices of domestic coal from 1913 to 1918 in the United States as a whole, and in the Carterville-Herrin district in Illinois. Similar graphs for the Mount Olive, Springfield, and Standard districts may be found in the 1918 Mineral Resources volume.

As the inquiry into prices centered about the effect of the war, the charts were made to show the movement of prices away from the pre-war level. This effect was produced by treating the average actual prices in the 12 months preceding the outbreak of the war (July, 1913, to June, 1914, inclusive) as equal to 100, and throwing the actual prices in each month from January, 1913, to December, 1918, into the form of relative prices on that scale. For example, if the selling price of coal averaged $2 a ton in the 12 months before the war, and if it fell to $1.80 in October, 1914, the chart would show the relative price for that month as 90; and if the price rose to $4.60 in July, 1918, the chart would show the relative price as 230.

The marketing methods of different producers vary, but in general they dispose of their coal in four ways: (1) on the open market, (2) under contract to jobbers, (3) through a sales agency on commission, and (4) under contract to consumers. The money taken in by producers from these four sources is termed the "realization price." Jobbers dispose of the coal they buy on the open market to a large extent, and all in all a large proportion of the coal goes through the open market before it reaches the consumer. The prices paid on the open market are called the "free" or "spot prices." Spot prices may be higher or lower than contract prices, according to circumstances. They are as a rule, lower in summer because of slack demand, and higher in winter. Spot prices are often lowest in April because in that month demand is lowest and buyers are concerned in negotiating for the lowest possible prices for the ensuing year's contracts.

Both spot and realization prices are studied and compared by the Fuel Administration but for purposes of this report, either kind would serve. The diagrams given as figure 11 were made to represent "spot" prices, which are the ones of greatest immediate interest to the greatest number of consumers. The explanation of the two graphs is as follows:

A.—Production, 1917, 28,000,000 net tons. Average spot price, pre-war period, $1.16; average realized price, $1.16.

1-5. The average monthly quotations for Carterville and Franklin County coal on the St. Louis market in the period beginning with 1913 to the first half of 1915 ranged from $1.19 in January, 1913 (1), to a low point in June, 1913, of $1.08 (2), and to $1 in November, 1914 (4), and the high price in January, 1914, of $1.28 (3), and in February, 1915, of $1.25 (5).

6. The maximum average monthly quotation for the six-year period covered by this report was for January, 1917, $3.30 (6).

7. Prevailing quotations in May and June, 1917, when the Peabody prices were established were around $3.19 (7).

8. The prices in July and August, during which the Peabody agreement was in effect, are indicated at (8).

9. The prices established by the President at the end of August, 1917, are indicated at (9).

10. The increase of 45 cents per ton allowed the operators to cover the advance in mine wages authorized in November, 1917, is indicated at (10).

11. The general reduction of 10 cents per ton ordered by the Fuel Administrator on May 25, 1918, is indicated at (11).

B.—Production, 1917, 551,790,000 net tons. Average spot price, pre-war period, $1.27; average realized price, $1.17.

1, 2. The downward trend of the price of bituminous coal in 1913, 1914, and 1915, is shown by both the spot prices and the average prices realized. From a general average spot price of $1.47 in January, 1913 (1), prices declined to $1.14 in July, 1915 (2).

3. The strength of the demand in the winter of 1915-16 particularly manifested in the Eastern States, is indicated by the rise in the general average spot price to $1.54 (3).

4. The highest point reached by the general average spot price was $3.77 in June, 1917 (4).

5. The amount of reduction effected by the Peabody prices is well illustrated by the drop in the curves from (4) to (5).

6. Likewise, the further decrease in the general level of prices brought about by the President's price of August 21, 1917, is shown by the drop in the curves from (5) to (6).

7. The general effect on prices of bituminous coal of the wage advance in November, 1917, is indicated by the rise from (6) to (7).

8. Advances in price in various fields authorized by the Fuel Administration as the result of investigations of the cost of mining raised the general level gradually to a maximum under Government control in May, 1918 (8).

9. The general reduction in price of 10 cents a ton on all bituminous coal ordered May 25, 1918, is reflected in the curves at (9).

The spot prices used in making the charts were taken from the weekly market quotations in the trade paper, the Coal Age, and the average realization prices referred to from annual reports of operators compiled by the U. S. Geological Survey.

TABLE 19.—*Average price per short ton of Illinois coal at mines, 1905-1918*

1905	$1.06
1906	1.08
1907	1.07
1908	1.05
1909	1.05
1910	1.14
1911	1.11
1912	1.17
1913	1.14
1914	1.12
1915	1.09
1916	1.25
1917	1.88
1918	2.32

FRONTIER AND CIVIL WAR PERIODS, 1818-1868

During the Frontier and Civil War periods, that is, from 1818 to 1868, few new industries had their beginnings. Although the exact date for these few are lost in obscurity, it is probably correct to list them as the iron, coke, clay products, cement, and sand and gravel industries.

IRON

The iron production given in Table 20 is not included in the total of Illinois' mineral production, because it represents merely the quantity and value of the metallic iron which is extracted in the State from iron ore that originates in the Lake Superior region. The State's own iron industry, based on ore produced within its own boundaries, is dead, and so nearly forgotten that its one-time existence comes as a surprise to many. Iron is one of the most nearly universally distributed elements in the earth's crust and Illinois has iron deposits which in the days when known deposits were less plentiful could be mined and smelted with profit. Though iron ore was sought in many places in the State, and as late as 1870 was seriously considered as a

possible resource still to be developed in the not distant future, it was only in Hardin County that an indigenous iron industry really existed. Its story is found in two paragraphs in the old Geological Survey of Illinois.[1]

TABLE 20.—*Production in long tons and value of pig iron in Illinois, 1907-1918*

Year	Quantity	Value	Average price per ton	Year	Quantity	Value	Average price per ton
1907......	2,457,768	$52,229,000	$21.25	1913.....	2,892,263	$45,796,966	$15.83
1908......	1,691,944	30,135,000	17.81	1914.....	1,793,714	24,382,458	13.59
1909......	2,467,156	44,211,000	17.92	1915.....	2,455,894	34,207,901	13.93
1910......	2,675,646	42,917,362	15.91	1916.....	3,857,391	67,764,309	17.57
1911......	2,036,081	31,152,927	15.30	1917.....	3,458,126	91,094,541	26.24
1912......	2,806,378	42,828,816	15.26	1918.....	3,409,876	105,415,030	30.91

"Two furnaces have been in operation in this county, both smelting the limonite ores, . . . with charcoal, of which the heavily timbered lands of the adjacent region have furnished an abundant supply. The Illinois Furnace . . . was built about the year 1837, and rebuilt and enlarged in 1856, and continued operations until the beginning of the rebellion in 1861, when it was stopped. It is 32 feet in height; the hearth and inner walls are built of sandstones of the Chester group, and the outer walls of limestone. (Both materials are from locally outcropping rock strata.) The blast was furnished by two horizontal double-acting cylinders driven by steam power and could be applied either hot or cold. The flame at the top of the furnace was conducted under a steam boiler, and then round a heating apparatus for the blast, and escaped thence through a chimney. The ore was first burned on log-heaps to expel the water and prepare it for the furnace. Two hundred bushels of charcoal, from oak and other hard woods (which originally covered the county in dense forests), were consumed in the production of a ton of pig iron, and this furnace is said to have yielded nine tons of pig metal every twenty-four hours. It was usually run from six to nine months of the year, according to the facility with which the ore was obtained. The metal produced was of excellent quality and always commanded the highest market price.

"The Martha Furnace . . . situated on Hog Thief Branch . . . smaller than the Illinois Furnace, was built in 1848 and stopped in 1857, and is now in a dilapidated condition. It usually ran about eight months of the year. The ore for these furnaces usually cost from one and three-quarters to two dollars per ton, at the furnaces, and the charcoal four cents per bushel."

[1]Worthen, A. H., Geology of Hardin County: Geol. Survey of Illinois, Vol. I, p. 365, 1866.

COKE

Just as the early iron industry of Illinois died and was replaced by an industry nominally the same but in reality different because dependent on raw materials from other states, so an early coke industry thrived on Illinois coal but was later replaced by a far larger coke industry using coal mined in the east. The available statistics (Table 21) date from 1880 and show the decline from eighth place among the states in that year to twenty-third place in 1904 and 1905, followed by a rise to fourth place in the ensuing period. The earlier period of maximum production followed upon the exhaustion of timber in sufficient abundance for charcoal for use of the iron furnaces. Better coke was to be had in the east, but the high cost of transportation in the days of few railroads outweighed the advantage of eastern over Illinois coke, and iron smelters were content to establish themselves in the midwest centers of population near the supplies of raw material for their coke. And so for many years the coke industry thrived on Illinois coal, quantities of fuel for blast furnaces being manufactured at Carterville, St. Johns, Brussels, Equality, Brookside, and Streator. Especially was the industry important in the Big Muddy valley, favorably situated south and east of St. Louis, for in the Big Muddy coal field was found some of the very best coal for coking purposes in the State. With the marvelous cheapening of transportation that marked the decades following 1890, New River and Pennsylvania cokes moved at so reasonable a cost into the markets fed by the Illinois product that consumers found it economy to use the superior eastern article in place of the inferior product from the impure Illinois coals. By 1893 attempts to make metallurgical coke from Illinois coal was abandoned and the little that was made was chiefly for use in the manufacture of water gas and for domestic use as crushed coke. The coke manufacturers were not even permitted to enjoy that small market undisputed, and the decline continued into the early years of the new century. The prodigious increase after 1904 was heralded by the completion at South Chicago in 1905 of a bank of 120 Semet-Solvay by-product ovens using coal drawn from the field of Fayette County, West Virginia.[1]

Prior to 1900 the concentration of enormous coke production in the beehive coke oven fields of Pennsylvania and West Virginia rendered impossible the absorption of more than a small fraction of the gas and other potentially valuable materials evolved in coke manufacture, and the enormous remainder was not readily transportable to outside areas. A solution for the difficulty was found in the transfer of the raw material from the good coke-coal fields to such places for manufacture as Chicago, where great quantities of coke were demanded by near-by steel mills and where the by-products, particularly the gas, might find a market that would more than pay coal transportation costs.

[1]United States Geological Survey, Mineral Resources of 1905, p. 740.

With the beginning of the State's new coke industry in 1905, then, the ends of conservation were served by stopping the great waste of the nation's coal resources involved in the use of the beehive coke oven and at the same time Illinois gained a great industrial asset. In five years after the first by-product ovens were put in operation the last of the beehive coke was pro-

Table 21.—*Statistics of the manufacture of coke in Illinois, 1880-1918*

Year	Establishments	Ovens: Built	Ovens: Building	Coal used	Yield of coal in coke	Coke produced	Total value of coke at ovens	Value of coke at ovens per ton	Rank of State
				Short Tons	*Per cent*	*Short tons*			
1880	6	176	0	31,240	41	12,700	$ 41,950	$3.30	8
1881	6	176	0	35,240	42	14,800	45,850	3.10	8
1882	7	304	0	25,270	45	11,400	29,050	2.55	8
1883	7	316	0	31,170	43	13,400	28,200	2.10	9
1884	9	325	0	30,168	43	13,095	25,639	1.96	10
1885	9	320	0	21,487	48	10,350	27,798	2.68	10
1886	9	335	0	17,806	46	8,103	21,487	2.65	11
1887	8	278	0	16,596	55.5	9,108	19,594	2.13	15
1888	8	221	0	13,020	56.9	7,410	21,038	2.84	16
1889	4	149	0	19,250	60	11,583	29,764	2.57	13
1890	4	148	0	9,000	55	5,000	11,250	2.25	18
1891	1	25	0	10,000	52	5,200	11,700	2.25	17
1892	1	24	0	4,800	66	3,170	7,133	2.25	18
1893	1	24	0	3,300	66.7	2,200	4,400	2.00	21
1894	1	24	0	3,800	57.9	2,200	4,400	2.00	21
1895	3	129	0	3,600	62.5	2,250	4,500	2.00	20
1896	3	127	0	3,900	66.7	2,600	5,200	2.00	20
1897	2	126	0	3,591	43	1,549	2,895	1.87	20
1898	2	126	0	6,650	35	2,325	4,686	2.02	19
1899	3	130	26	....	....	*a*2,370	*a*5,565	....	22
1900	3	154	0	*b*	*b*	*b*	*b*	*b*	22
1901	2	154	0	*b*	*b*	*b*	*b*	*b*	22
1902	2	149	0	*b*	*b*	*b*	*b*	*b*	22
1903	2	155	0	*b*	*b*	*b*	*b*	*b*	23
1904	5	155	120	8,131	54.6	4,439	9,933	2.24	23
1905	5	275	....	16,821	61.3	10,307	27,681	2.69	22
1906	4	309	....	362,163	74.2	268,693	1,205,462	4.48	14
1907	5	309	280	514,983	72.3	372,697	1,737,464	4.66	10
1908	6	430	140	503,359	72.0	362,182	1,538,952	4.25	8
1909	5	468	40	1,682,122	75.9	1,276,956	5,361,510	4.20	4
1910	5	508	....	1,972,955	76.8	1,514,504	6,712,550	4.43	4
1911	4	506	48	2,087,870	77.1	1,610,212	6,390,251	3.97	4
1912	6	594	40	2,316,307	76.2	1,764,944	8,069,903	4.57	5
1913	4	568	58	2,481,198	74.9	1,859,553	8,593,581	4.62	5
1914	4	*c*586	*d*40	1,932,132	73.8	1,425,168	5,858,700	4.11	5
1915	4	*e*626	....	2,335,933	72.2	1,686,998	7,016,635	4.16	4
1916	4	*e*626	....	3,182,650	72.9	2,320,400	10,619,066	4.57	5
1917	4	626	....	3,233,669	70.8	2,289,833	14,455,539	6.31	6
1918	4	626	*f*88	3,199,620	71.4	2,285,610	18,625,436	8.15	6

a Includes Indiana.
b Less than three producers. Statistics concealed.
c Includes 253 Semet-Solvay, 315 Koppers, and 18 Wilputte ovens.
d Semet-Solvay ovens.
e Includes 293 Sement-Solvay, 315 Koppers, and 18 Wilputte ovens.
f Wilputte ovens.

duced and three years later the beehive plants had been permanently dismantled.

Some of the most noteworthy events in the industry's recent history are as follows:

1899. Four Hemingway process experimental ovens, which were of the beehive type but were nevertheless designed to save the by-products, were completed in that year, and 26 additional ovens were under construction.

1900. All the coke produced in the State was made in the Hemingway ovens in Chicago.

1905. A bank of 120 Semet-Solvay ovens was completed at South Chicago and put in blast in October, using coal drawn from the fields of Fayette County, West Virginia. Of the four other establishments in the State, only one, the Gallatin Coal and Coke Company of Equality, made coke in 1905 and 1906.

1907. At Joliet 280 Koppers ovens were under construction. Only the Semet-Solvay South Chicago plant and the Equality plant reported production.

1908, 1909. Koppers ovens at Joliet put in blast.

1910. Last beehive coke produced in the State.

1912. At Joliet 35 more Koppers ovens and at Waukegan 13 Semet-Solvay ovens were put in blast.

1914. At Joliet 18 Wilputte ovens were completed.

1915. At South Chicago construction of new ovens brought the total number of Semet-Solvay ovens up to 280.

CLAY PRODUCTS

The exact date of the first use of Illinois clay must remain unknown, for the Indians made use of it long before the coming of white men—witness, for example, the description of clay evaporating pans, fragments of which were found around the brine springs of Gallatin County. But this use or even the early use of clay as a plaster for chinks in the pioneers' homes can not be considered as any real development of the resources, and it was probably not until after 1818 that systematic exploitation began.

Once begun, the clay working industries developed with much the same rapidity as did the coal industry. During the period when coal production increased fourfold, clay products increased fully threefold, both in the pot-

tery and in the brick and tile subdivisions of the industry. For many years now, brick and tile manufactures have far outranked pottery. In the early days, however, the reverse was true, for neither the great bulk of the State's clay resources, nor the need for brick for construction and tile for drainage, were apparent while population was still confined to a large extent to the wooded areas along major stream lines. With expansion into the prairies, however, the brick and tile phase soon outstripped pottery.

A few words as to the common building brick and drain-tile production will serve as a comment on the whole industry, for these two branches are typically representative.

Common brick is in considerable demand over most of the State because of lack of stone of suitable quality and in sufficient quantity for building purposes. Draintile, too, is in almost state-wide demand, because of the natural inadequacy of drainage over a large portion of the State as a result of glaciation; and because even in the unglaciated areas, drainage problems are presented in the broad floodplains of the Mississippi, the Ohio, the Wabash, and their larger tributaries. Very fortunately, the need for common brick and draintile is well matched by not far distant supplies of raw material suitable for the manufacture of these products. The relation is particularly

TABLE 22.—*Production in short tons, and value of fire clay and other clays mined and marketed in Illinois, 1902-1918*

Year	Fire clay		Other clays		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1902	(*a*)	(*a*)	(*a*)	(*a*)	52,152	$ 38,463
1903	36,239	$ 38,027	34,799	$35,815	71,038	73,842
1904	55,922	43,863	33,043	27,223	88,965	71,086
1905	50,922	53,726	76,806	66,684	127,728	120,410
1906	44,989	50,793	94,715	81,479	139,704	131,272
1907	66,525	55,545	57,250	50,158	123,775	105,703
1908	39,075	47,039	78,007	67,443	117,082	114,482
1909	45,806	73,884	98,254	76,984	144,060	150,868
1910	82,878	111,078	105,925	79,818	188,803	190,896
1911	71,479	91,623	111,357	92,203	182,836	183,826
1912	92,963	110,204	83,595	82,459	176,558	192,663
1913	106,216	125,477	88,721	78,560	194,937	204,037
1914	125,071	138,876	36,013	29,478	161,084	168,354
1915	93,888	120,008	70,016	49,312	163,904	169,320
1916	131,658	327,666	66,043	50,774	197,701	378,440
1917	150,655	736,568	45,038	53,021	195,693	789,589
1918	133,585	372,295	35,597	41,606	169,182	413,901

a Concealed in "Total."

TABLE 23.—*Clay products in Illinois, 1909-1918*

Product	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
Brick:										
Common—										
Quantity	1,257,025,000	1,196,526,000	1,074,486,000	1,210,499,000	1,155,480,000	941,343,000	1,066,057,000	1,182,473,000	738,963,000	365,958,000
Value	$5,927,054	$6,896,836	$6,126,911	$6,437,331	$6,445,821	$4,898,698	$6,870,990	$6,738,152	$5,138,822	$3,218,758
Average per M	$4.72	$5.76	$5.70	$5.32	$5.58	$5.20	$6.45	$5.70	$6.95	$8.80
Vitrified—										
Quantity	140,105,000	115,903,000	124,623,000	136,708,000	133,938,000	157 176,000	142,689,000	175,989,000	171,067,000	83,832,000
Value	$1,562,373	$1,415,355	$1,627,683	$1,839,721	$1,883,199	$2,086,344	$1,796,350	$2,465,179	$2,530,046	$1,390,149
Average per M	$11.15	$12.21	$13.06	$13.46	$14.06	$13.27	$12.59	$14.02	$14.79	$16.58
Front—										
Quantity	32,416,000	22,138,000	19,786,000	21,894,000	29,566,000	46,995,000	58,107,000	74,652,000	63,074,000	29,355,000
Value	$385,170	$274,699	$240,135	$268,433	$363,010	$506,984	$635,686	$810,440	$785,056	$451,173
Average per M	$11.88	$12.41	$12.14	$12.26	$12.28	$10.79	$10.94	$10.92	$12.45	$15.37
Fancy or ornamental, value	$12,223	$10,875	$10,281	$8,785	$2,295	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)
Enameled value	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)
Fire value	$682,793	$368,730	$286,039	$319,619	$351,324	$274,106	$320,740	$523,442	$936,260	$1,040,855
Stove lining value	.....	.....	.....	.....	.....	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)
Draintile value	$1,613,593	$1,613,698	$1,372,049	$1,189,910	$1,225,190	$1,041,927	$991,709	$1,200,465	$1,314,006	$1,077,861
Sewer pipe value	$394,461	$538,633	$507,694	$500,844	$787,896	$743,986	$569,536	$768,410	$997,419	$903,889
Architectural terra cotta value	$1,898,865	$1,680,438	$1,879,275	$2,485,012	$1,908,399	$1,652,945	$1,289,848	$1,980,781	$2 060,954	$831,230
Fireproofing value	$439,796	$552,905	$552,994	$507,222	$592,337	$567,266	$492,138	$769,929	$1,136,975	$981,130
Tile, not drain value	$335,020	(*a*)	(*a*)	(*a*)	$82,168	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)
Pottery:										
Red earthenware value	$31,771	$25,658	$41,875	$35,827	$46,175	$37,452	$40,810	$46,843	$51,787	$42,853
Stoneware and yellow and Rockingham ware value	$702,411	$708,958	$832,813	$675,244	$624,194	$483,407	$572,958	$548,633	$796,194	$930,176
White ware including C. C. ware, white granite, semiporcelain ware and semivitreous porcelain ware value	(*a*)	.....	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)
Sanitary ware value	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)
Porcelain electrical supplies value	.....	.....	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)
Miscellaneous value	$358,923	$1,089,376	$855,262	$943,042	$883,866	$1,025,838	$1,211,173	$1,781,077	$3,817,901	$5,004,788
Total value	$14,344,453	$15,176,161	$14,333,011	$15,210,990	$15,195,874	$13,318,953	$14,791,938	$17,633,351	$19,565,420	$15,872,862
Number of active firms reporting	379	346	330	301	281	263	254	213	225	207
Rank of State	4	4	4	4	4	4	4	4	4	4

a Included in "Miscellaneous."

TABLE 24.—*Production of brick and draintile in Illinois, by counties, 1917*

County	Common Brick		Draintile	Other Brick and tile products	Total value
	Thousands	Value	Value	Value	
Adams	4,538	$ 38,550	....	(*a*)	$ 38,750
Bureau	1,828	13,166	$ 51,477	$142,232	206,875
Cass	(*a*)	(*a*)	(*a*)	....	8,570
Champaign	(*a*)	(*a*)	....	(*a*)	23,547
Christian	1,031	7,858	14,859	....	22,717
Cook	497,235	3,326,230	(*a*)	1,989,863	5,331,325
Edwards	(*a*)	(*a*)	(*a*)	143,456	181,864
Fulton	5,900	40,100	(*a*)	(*a*)	68,162
Hancock	679	5,680	(*a*)	(*a*)	38,466
Iroquois	(*a*)	(*a*)	61,737	....	62,037
Kane	(*a*)	(*a*)	(*a*)	(*a*)	35,602
Kankakee	(*a*)	(*a*)	251,750	303,215	738,876
Lake	21,793	112,936	(*a*)	....	113,616
La Salle	(*a*)	(*a*)	188,697	1,359,981	1,573,028
Livingston	(*a*)	(*a*)	47,516	818,735	941,583
McDonough	(*a*)	(*a*)	74,666	487,078	572,844
Macoupin	(*a*)	(*a*)	(*a*)	(*a*)	27,850
Madison	8,812	69,415	(*a*)	355,863	449,278
Montgomery	342	2,741	(*a*)	(*a*)	58,403
Morgan	814	6,366	(*a*)	....	11,061
Rock Island	(*a*)	(*a*)	(*a*)	46,166	79,549
St. Clair	(*a*)	(*a*)	(*a*)	67,968	220,507
Saline	(*a*)	(*a*)	(*a*)	(*a*)	33,300
Sangamon	5,749	39,303	24,300	270,142	333,745
Tazewell	(*a*)	(*a*)	(*a*)	60,447	191,863
Vermilion	(*a*)	(*a*)	(*a*)	747,002	1,313,811
White	(*a*)	(*a*)	8,775	....	11,785
Will	(*a*)	(*a*)	(*a*)	(*a*)	2,218,487
Other counties[b]	28,113	226,364	417,921	2,484,841	3,086,657
State totals	738,968	$5,138,822	$1,314,006	$11,541,330	$17,994,158

a Concealed in totals.

b Including Boone, Clinton, Douglas, DeWitt, Dupage, Edgar, Effingham, Fayette, Gallatin, Greene, Grundy, Hamilton, Henry, Jackson, Jersey, Knox, Lawrence, Lee, Logan, McHenry, McLean, Macon, Marion, Mason, Massac, Menard, Mercer, Monroe, Moultrie, Ogle, Peoria, Pike, Pulaski, Randolph, Richland, Schuyler, Scott, Shelby, Stark, Warren, Washington, Williamson, and Woodford counties.

TABLE 25.—*Production of brick and draintile in Illinois, by counties, 1918*

County	Common Brick		Draintile	Other brick and tile products	Total value
	Thousands	Value	Value	Value	
Adams	3,765	$ 36,778	....	(*a*)	$ 37,138
Bureau	1,240	11,940	$ 25,300	(*a*)	175,998
Christian	554	7,310	11,482	....	18,792
Cook	200,014	1,508,623	(*a*)	$ 793,661	2,355,804
Edwards	(*a*)	(*a*)	....	69,668	99,685
Fulton	(*a*)	(*a*)	(*a*)	....	60,366
Hancock	(*a*)	(*a*)	(*a*)	(*a*)	19,239
Iroquois	(*a*)	(*a*)	40,148	....	40,248
Kankakee	(*a*)	(*a*)	276,410	192,269	527,427
La Salle	(*a*)	(*a*)	146,850	1,412,334	1,589,524
Livingston	(*a*)	(*a*)	34,141	625,936	737,985
McDonough	(*a*)	(*a*)	(*a*)	587,246	637,532
Macoupin	(*a*)	(*a*)	(*a*)	(*a*)	13,750
Madison	9,489	118,635	(*a*)	247,885	386,520
Morgan	360	3,850	(*a*)	....	9,100
Rock Island	(*a*)	(*a*)	(*a*)	(*a*)	40,907
St. Clair	(*a*)	(*a*)	....	(*a*)	183,666
Saline	3,280	34,200	(*a*)	(*a*)	43,400
Sangamon	4,743	38,982	(*a*)	208,141	250,523
Tazewell	(*a*)	(*a*)	(*a*)	(*a*)	175,508
Vermilion	(*a*)	(*a*)	....	1,156,115	1,884,190
White	(*a*)	(*a*)	6,550	....	14,950
Other counties (*b*)	20,113	196,799	353,507	4,246,154	4,752,682
State totals	365,958	$3,218,758	$1,077,861	$9,806,508	$14,103,127

a Concealed in totals.

b Including Boone, Clinton, Douglas, DeWitt, Dupage, Edgar, Effingham, Fayette, Gallatin, Greene, Grundy, Hamilton, Henry, Jackson, Jersey, Knox, Lawrence, Lee, Logan, McHenry, McLean, Macon, Marion, Mason, Massac, Menard, Mercer, Monroe, Moultrie, Ogle, Peoria, Pike, Pulaski, Randolph, Richland, Schuyler, Scott, Shelby, Stark, Warren, Washington, Williamson, and Woodford counties.

noteworthy in the case of draintile: glaciation is responsible for poor drainage conditions, but at the same time glacial deposits afford practically inexhaustible quantities of clay for draintile with which to remedy the defect.

In 1918 Cook County led all others in production of common brick, with 55 per cent of the State's total production. Density of urban population and the plentiful supply of glacial clay explain the magnitude of the industry here. Kankakee County led in draintile production, reporting 26 per cent of the State's output. Extensive marshes and swamps in Kankakee and adjoining counties, which need enormous quantities of tile for their complete reclamation, serve to insure leadership of that county in this branch of the industry. In a lesser degree the same conditions that induce large production of brick and draintile in these two counties operate over a large share of the State, for in 1918 forty-two counties reported production of draintile and forty-six, common brick.

A significant feature of the industry is the almost unbroken decrease in the number of manufacturers of clay products from a maximum of 697 in 1894 to a minimum of 168 in 1918. In this progressive change is one of the most marked examples of the modern tendency toward concentration and centralization which is operating in so many of the mineral and other industries.

What with raw materials, coal for kilns, easy transportation to facilitate not only marketing but also importation of raw materials necessary for certain products, and a market capable of absorbing enormous quantities of all sorts of clay products, it is to be expected that Illinois would rank high among the states. Only Ohio, Pennsylvania, and New Jersey surpass it in total value of clay products, and considering brick and tile production alone, Illinois takes third place from New Jersey.

CONDITION OF THE INDUSTRY IN 1917 AND 1918

The years 1917 and 1918 brought unusual conditions in the clay-working as in most industries. Since the country was at war, structural work, which in Illinois normally consumes more than 60 per cent of the clay products, used only 53 per cent in 1917 and 44 per cent in 1918, these percentages corresponding to decreases of about one million and three and a half million dollars respectively; the clay products used chiefly in engineering works—vitrified paving brick or block sewer pipe and draintile suffered comparable decreases; and even the refractories which were of vital importance to many industries related to the war, decreased slightly in quantity though not in value in 1918 as compared with 1917.

High cost and scarcity of materials and labor, and inadequate transportation facilities are the causes inducing the decreases. The marked decline in general building on account of war conditions and Government restrictions is reflected in the large decreases in clay products for structural mate-

rials. The maintenance of the demand and the greatly increased prices of refractories was due to the demand for them in the iron and steel and allied industries.

Among the Government restrictions which affected the clay working industries was curtailment of fuel supply. The Fuel Administration allowed to the operators percentages of their average coal consumption in 1915, 1916, and 1917 as follows: 50 per cent for common brick, paving brick, face brick, terra cotta, roofing tile, floor and wall tile, and sanitary ware; 75 per cent for hollow tile, sewer pipe, draintile and flue lining; and 85 per cent for stoneware, except chemical stoneware which was not restricted. Statistics show that whereas the average annual coal consumption by the clay working industries of Illinois in 1915, 1916, and 1917 was 1,064,904 tons, during the first half of 1918, the actual consumption was only 236,297 or a saving of 296,155 tons in half a year. It is probable that the saving for the whole year would be even greater comparatively speaking, for many concerns chose to operate at full capacity until their fuel allowance was exhausted and then shut down for the remainder of the year.

In common brick production, Illinois led in 1917, but was displaced by Pennsylvania in 1918. Illinois' output of common brick in 1918 decreased 373,005,000 bricks, or 50 per cent, and the value decreased $1,920,064, or 37 per cent as compared with 1917. It is interesting to mention that the proportionate decrease in common brick production was greater in Cook County in 1918 than it was in the State at large, indicating that the falling off in building operations (where common brick finds its almost exclusive use) was greater in Chicago than in the smaller cities and towns.

In the production of draintile, Iowa, Ohio, Indiana, and Illinois, in the order given, continued to be the leading states. All these states reported large decreases in 1918, Illinois for example suffering a decrease in value of $236,145, or 18 per cent.

As for many years, Illinois was the leading state in production of architectural terra cotta, reporting 31 per cent of the total United States production in spite of a decrease of $1,229,724 or 60 per cent in 1918 as compared with 1917.

CEMENT

The cement industry of Illinois, like the coke and the iron industries, has two separate and distinct phases, the earlier based on natural cement production, and the more recent on Portland cement manufacture.

At Utica on Illinois River the early settlers discovered abundant supplies of natural cement materials, and since 1838, when the first cement was manufactured in Illinois by James Clark of Utica, the plant has been in constant active operation. Records indicate that there were only two other cement plants in the United States in 1838, the one at Fayetteville, New York, established in 1818, and the other at Shippingsport, Kentucky, started in 1829.

Perhaps no more strategic position than the vicinity of Utica could be imagined for such a resource: in the ante-railroad days Illinois River furnished a ready line of transportation to the markets west and south where most of the population lay; later, with the building of the Illinois and Michigan Canal, in the construction of which Utica natural cement played an extensive part, an easy way was opened to the markets in growing Chicago, as well as at points east by way of the lakes; still later, the great markets of the prairies were opened when railroad lines focused themselves on the La Salle-Utica area, attracted by glass-sand quarries, cement plants, and abundant coal supply; and from the very first the proximity of coal to the cement deposits helped make the Utica area an ideal one in which the industry might early begin and continue to thrive. Proof of the excellence of conditions there is found in the fact that when Portland cement plants

TABLE 26.—*Portland cement industry in Illinois, 1900-1918*
(Figures opposite P relate to production; those opposite S to shipments.)

Year		Number of plants	Quantity	Value	Average price per barrel
			Barrels		
1900	P	3	240,442	$ 300,552	$1.25
1901	P	4	528,925	581,818	1.10
1902	P	4	767,781	977,541	1.27
1903	P	5	1,257,500	1,914,500	1.52
1904	P	5	1,326,794	1,449,114	1.09
1905	P	5	1,545,500	1,741,150	1.13
1906	P	4	1,858,403	2,461,494	1.33
1907	P	5	2,036,093	2,632,576	1.29
1908	P	5	3,211,168	2,707,044	.84
1909	P	5	4,241,392	3,388,667	.80
1910	P	5	4,459,450	4,119,012	.90
1911	P	5	4,582,341	3,583,301	.79
1912	P	5	4,299,357	3,212,819	....
	S	5	4,602,617	3,444,085	.75
1913	P	5	5,083,799	5,109,218	....
	S	5	4,734,540	4,784,696	1.01
1914	P	5	5,401,605	5,007,288	....
	S	5	5,284,022	4,848,522	.92
1915	P	4	5,156,869	....	....
	S	5	5,435,655	4,884,026	.90
1916	P	4	3,642,563	....	....
	S	4	3,562,659	3,386,431	.95
1917	P	4	4,659,990	....	....
	S	4	4,378,233	6,090,158	1.39
1918	P	4	3,594,038	....	....
	S	4	3,703,471	5,695,186	1.54

FIG. 12. Value of natural and Portland cement in Illinois, 1888-1918.

came into existence, they were established early in this very area, and the two branches have continued to exist side by side in La Salle County.

The natural cement industry in Illinois was one of wide extent in the past, shipments going far from the State in the days when cements were more difficult to obtain than they are now; but especially in the upbuilding of the large cities of Illinois natural cement played an important part.

In spite of the excellence of the Utica product, the standardization possible in the artificial cement combines with the far wider availability of the necessary raw materials to make the Portland cement industry supreme. The construction of the Chicago Portland Cement Company's plant in 1894 marked the beginning of that phase of the industry (fig. 12). The value of the 300 barrels produced that year was $540, negligible figures as compared with

the 1917 totals of more than four and one-half million barrels and six million dollars. Engineers were at first slow to take up with the proposed substitute for the old, tried, natural cement, but when once the Portland cement proved satisfactory, the rapidity and steadiness of increase was phenomenal. Five large plants, located at Dixon, Oglesby, Utica, and La Salle, are now apparently somewhat inadequate; for the U. S. Geological Survey estimates a deficiency in local supply of 2,811,429 barrels in 1917 and 1,222,265 barrels in 1918. Of course, it must be taken into account that the deficiency is in part or perhaps wholly apparent only rather than real, for there is a large importation of cement from extreme northwestern Indiana into the immediately adjacent Chicago district of large population and consumption. So centralized and carefully controlled is the cement industry that there is no danger of a serious shortage of local cement supply for any prolonged period.

SAND AND GRAVEL

The sand and gravel resources of Illinois are enormous—not only are deposits of sands and gravels widespread in the drift and associated glacial deposits, but the St. Peter sandstone of La Salle, Lee, and Ogle counties constitutes a large and important source of very pure silica sand which finds one of its special uses in the manufacture of glass.

Statistics of production were not taken until comparatively recent years and references to sand and gravel are so few in early reports that it is practically impossible to state even an approximate date for its first use in the State. However, it is deemed safe to place the beginning of this industry prior to 1870.

Tables 27, 28, and 29 give the present status of the industry as well as can any description, for they show its widespread character and the great variety of uses to which the product is put. It is interesting to note in addition that Illinois ranked first in sand and gravel output in 1917 and second in 1918; in value of output, however, it ranked third in both years.

The Status of Mineral Industries in 1868

The close of the first half of the century in 1868 saw the beginning of no industries other than those that have been discussed. By that time the foundations had been laid for industries of prime importance—coal, stone, clay products, and cement; and by that time the one-time prosperous salt and indigenous iron industries were fast dying out, unable to stand the competition with better deposits developed in other states. In short, those industries that were based on Illinois' possession of abundant resources unexcelled in near-by areas lived, while those not so favored died. All through the half century ending in 1868, lack of adequate transportation hampered development so markedly that the growth in the following fifty years when the State was in effect suddenly freed from this restraint was indeed startling.

TABLE 27.—*Production in short tons, and value of sand*

County	Producers	Glass sand		Molding Sand		Building Sand		Grinding and polishing sand		Fire or furnace sand
		Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity
Bond	5			32,061	$27,528	(a)	(a)			
Bureau	10			(a)	(a)	(a)	(a)			
Cook	5					551,378	$228,086			
Kane	19			26,882	18,021	327,170	89,992			(a)
Kendall	3	(a)	(a)			37,397	18,420	(a)	(a)	
La Salle	23	494,791	$535,516	554,639	300,842	64,843	38,937	124,555	$159,495	84,577
Lee	4					(a)	(a)			
Livingston	3					2,161	1,143			
McHenry	8			(a)	(a)	286,806	78,993			
Madison	6			(a)	(a)	67,464	20,306			
Ogle	5	(a)	(a)			(a)	(a)			
Peoria	9			(a)	(a)	72,835	34,350			
Rock Island	9			21,940	11,701	(a)	(a)			
Tazewell	4					59,519	31,999			
Whiteside	3			(a)	(a)	(a)	(a)			
Will	10			(a)	(a)	218,820	62,789			
Winnebago	9			24,170	22,568	259,784	98,104			
Other counties *b*	30			43,156	31,966	644,597	229,346	(a)	(a)	
State total	165	607,186	$679,618	703,208	$412,626	2,592,774	$932,455	129,605	$167,414	(a)

a Concealed, either in "State Total," or with "Other Counties."
b Including: Adams, Alexander, Boone, Carroll, Cass, Crawford, DeKalb, Fayette, Ford, Fulton, Hancock, Henderson, Jo Daviess, Lake, Logan, McLean, Macon, Mercer, Pike, Pulaski, Putnam, Randolph, St. Clair, Schuyler, Vermilion, Wabash.

County	Producers	Glass sand		Molding sand		Building sand		Grinding and polishing sand		Fire or furnace sand
		Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity
Bond	6			41,788	$52,229	(a)	(a)			
Bureau	5			(a)	(a)	14,470	$ 6,605			
Cook	4					372,646	178,829			
Kane	12			61,595	43,707	136,737	39,160			
Kendall	3	(a)	(a)	(a)	(a)	(a)	(a)			
La Salle	25	645,565	$1,091,527	642,270	436,752	6,054	2,926	45,450	$136,890	88,800
Lee	3					(a)	–a)			
Livingston	3					2,338	783			
McHenry	7			(a)	(a)	220,098	74,111			
Ogle	4	(a)	(a)			(a)	(a)	(a)	(a)	
Peoria	8			(a)	(a)	26,179	14,383			
Rock Island	9			(a)	(a)	83,777	38,599			
Tazewell	4					54,155	32,755			
Will	7			65,392	51,738	119,182	39,766			
Winnebago	9			38,298	35,993	207,927	82,186			
Other counties *b*	35			36,274	37,786	588,632	246,785			
State total	144	760,835	$1,273,804	885,617	$658,205	1,832,195	$756,888	(a)	(a)	88,800

a Concealed, either in "State Total," or with "Other Counties."
b Including: Adams, Alexander, Boone, Carroll, Cass, Crawford, De Kalb, Fayette, Hancock, Jo Daviess, Lake, Lawrence, Logan, Macon, Madison, Marshall, Mercer, Pike, Pulaski, Putnam, Randolph, St. Clair, Schuyler, Vermilion, Wabash, White, Whiteside.

nd gravel in Illinois, by counties, 1917 and 1918

Fire or furnace sand	Engine sand		Paving sand		Other sands		Gravel		Total	
Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
....	....	....	....	....	....	....	....	....	33,411	$27,778
....	(a)	(a)	(a)	(a)	2,953	$ 639	89,582	$41,323	126,927	55,336
....	(a)	(a)	(a)	(a)	37,855	2,521	215,161	57,813	827,122	293,318
(a)	....	....	(a)	(a)	....	....	393,670	94,678	748,858	203,655
....	....	....	....	....	....	....	(a)	(a)	92,388	71,740
$54,360	(a)	(a)	(a)	(a)	69,505	13,102	161,686	74,990	1,563,511	1,179,531
....	....	....	....	....	....	....	14,735	4,926	22,410	7,776
....	....	....	(a)	(a)	....	....	3,361	1,257	7,222	3,250
....	....	....	(a)	(a)	750,000	75,000	197,169	53,616	1,490,218	244,661
....	(a)	(a)	(a)	(a)	7,550	3,658	(a)	(a)	105,077	38,921
....	....	....	....	....	(a)	(a)	(a)	(a)	508,947	202,749
....	(a)	(a)	(a)	(a)	11,719	1,478	88,714	49,016	174,710	85,966
....	....	....	49,621	$17,734	....	....	147,536	89,245	250,999	129,438
....	(a)	(a)	(a)	(a)	....	....	183,644	108,421	302,140	170,302
....	....	....	(a)	(a)	....	....	(a)	(a)	13,970	8,838
....	....	....	....	....	316,519	69,777	575,827	160,633	1,117,391	297,557
....	....	....	(a)	(a)	....	....	278,340	96,622	666,911	250,229
....	80,509	$18,933	475,813	122,781	499,969	99,993	298,230	149,043	1,068,486	387,754
(a)	133,715	$33,586	525,434	$130,515	1,696,070	$266,168	2,647,655	$981,583	9,120,698	$3,658,799

Fire or furnace sand	Engine sand		Paving sand		Other sands		Gravel		Totals	
Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
....	....	....	....	....	....	....	....	....	42,058	$ 52,429
....	....	....	(a)	(a)	4,675	$ 965	70,714	$33,912	97,509	45,482
....	(a)	(a)	....	....	64,239	7,255	195,463	65,357	656,488	254,406
....	....	....	....	....	....	....	186,585	57,430	384,917	140,297
....	....	....	....	....	....	....	(a)	(a)	58,716	49,184
$59,825	....	....	....	....	173,122	97,666	19,611	7,777	1,620,872	1,832,463
....	....	....	....	....	....	....	(a)	(a)	3,823	1,354
....	....	....	(a)	(a)	....	....	(a)	(a)	4,168	1,532
....	....	....	(a)	(a)	....	....	174,535	61,348	426,225	163,463
....	....	....	....	....	309,082	61,816	24,825	12,973	470,303	263,953
....	(a)	(a)	....	....	42,734	29,750	42,156	29,365	79,354	43,977
....	....	....	....	....	2,696	1,409	138,637	83,349	232,515	131,571
....	....	....	(a)	(a)	....	....	93,961	68,379	168,254	114,954
....	....	....	....	....	183,759	49,216	311,175	104,006	679,508	244,726
....	....	....	....	....	14,756	1,581	146,921	54,640	407,902	174,400
....	(a)	(a)	5,597	$ 1,521	142,558	26,789	237,237	66,043	1,022,794	475,705
$59,825	107,041	$31,589	54,925	$39,937	937,651	$276,447	1,641,820	$744,579	6,355,406	3,980,124

TABLE 28.—*Production in short tons and values of different kinds of sand and gravel in Illinois, 1904-1918*

Year	Glass sand		Molding sand		Building sand		Grinding and polishing sand		Fire and furnace sand	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1904	219,784	$ 143,954	574,488	$ 363,090	338,461	$ 148,911	....	....	44,360	$ 19,751
1905	234,391	146,605	336,247	189,423	244,297	111,212	....	....	13,307	5,312
1906	238,178	156,684	372,307	216,087	868,014	314,071	....	....	87,560	38,466
1907	235,716	152,619	372,884	237,149	1,067,776	419,450	....	....	22,668	15,017
1908	194,722	139,172	143,080	86,213	1,342,303	481,827	....	....	75,762	19,799
1909	224,381	153,226	288,518	143,922	1,917,915	632,273	....	....	25,210	15,173
1910	268,654	216,531	407,232	215,742	1,756,652	473,209	....	....	97,633	60,932
1911	251,907	171,978	237,359	120,690	1,875,814	691,846	59,880	$ 41,765	62,107	25,643
1912	323,467	225,434	540,728	268,521	1,910,911	598,884	67,040	49,196	(*a*)	(*a*)
1913	350,229	239,227	404,717	181,794	2,299,834	594,687	42,198	23,138	84,801	43,269
1914	339,551	246,803	347,543	200,011	1,996,873	383,209	58,351	38,780	60,674	24,569
1915	566,128	299,286	383,185	195,992	1,600,521	472,654	(*a*)	(*a*)	(*a*)	(*a*)
1916	487,432	318,235	632,529	313,219	2,059,259	597,771	168,088	152,432	(*a*)	(*a*)
1917	607,186	679,618	703,208	412,626	2,592,774	932,455	129,605	167,414	85,051	54,834
1918	760,835	1,273,804	885,617	658,205	1,832,195	756,888	46,450	139,390	88,800	58,925

Year	Engine sand		Paving sand		Other sands		Gravel		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1904	8,250	$ 2,120	....	....	21,328	$ 11,914	....	....	1,206,671	$ 689,740
1905	4,062	1,425	....	....	518,049	112,761	277,050	$ 127,034	1,627,403	693,772
1906	70,000	27,400	....	....	64,903	32,068	956,597	258,265	2,657,559	1,043,041
1907	113,742	29,091	....	....	940,746	133,090	1,797,459	381,237	4,550,991	1,367,653
1908	47,863	8,952	....	....	2,047,147	175,941	2,806,871	591,118	6,657,748	1,503,022
1909	104,882	11,242	....	....	3,188,885	277,056	3,405,438	716,605	9,155,229	1,949,497
1910	43,147	6,840	....	....	1,211,564	130,756	4,801,626	626,785	8,586,508	1,730,795
1911	46,897	6,158	318,671	$ 125,624	1,862,000	164,292	3,774,048	642,926	8,488,683	1,990,922
1912	59,151	12,916	30,581	13,958	499,685	75,391	3,481,638	664,552	6,957,901	1,929,822
1913	79,568	11,166	101,631	30,973	171,898	77,252	4,457,264	868,985	7,992,140	2,070,491
1914	93,299	12,239	121,812	39,851	522,808	120,635	4,955,219	793,422	7,696,130	1,859,519
1915	73,427	14,677	291,436	73,645	8,376	4,402	4,424,527	885,548	7,708,012	1,984,569
1916	67,979	12,143	90,843	32,803	1,500,942	312,887	3,358,153	847,947	8,365,225	2,587,437
1917	133,715	33,586	525,434	130,515	1,696,070	266,168	2,647,655	981,583	9,120,698	3,658,799
1918	107,041	31,589	54,925	39,937	937,723	276,807	1,641,820	744,579	6,355,406	3,980,124

TABLE 29.—*Glass sand produced in Illinois, 1903-1918*

Year	Quantity	Value	Average price per ton	
	Short tons		*Illinois*	*United States*
1903	255,440	$153,717	$0.60	$1.04
1904	219,784	143,954	.66	.90
1905	234,391	146,605	.63	1.05
1906	238,178	156,684	.66	1.11
1907	235,716	152,619	.65	1.05
1908	194,722	139,172	.71	.96
1909	224,381	153,226	.69	1.05
1910	268,654	216,531	.81	1.04
1911	251,907	171,978	.68	1.01
1912	323,467	225,434	.70	.97
1913	350,229	239,227	.68	1.06
1914	339,551	246,803	.73	.97
1915	566,128	299,286	.53	.85
1916	487,432	318,235	.65	.97
1917	607,186	679,618	1.12	1.38
1918	760,835	1,273,804	1.48	1.94

THE INDUSTRIAL PERIOD, 1868-1893

Only three minerals, petroleum, natural gas, and fluorspar, were added to the list of developed resources during the third quarter of the century from 1868 to 1893. Of these, the last has precedence in point of age.

FLUORSPAR

Until 1896 the only production of this mineral in the United States was from the deposits of Hardin County, which are known the world over as among the greatest yet discovered. In 1896 mines were opened in the adjacent Kentucky district, and a decided slump in Illinois production followed for five years. A strong revival of production began about 1902 and tonnage has increased, with considerable fluctuation, from that time to the present.

Fluorspar is used mainly in supplying the American market with spar for foundry work and steel making and its production consequently increases or decreases as the steel industry thrives or declines. Only a very small fraction—that containing less than one per cent silica—can be used in the enameling, chemical, and glass trades. A still smaller fraction of the material is sufficiently flawless and in pieces of adequate size for use in optical work.

The commercial importance of the Illinois fluorspar district is bound to grow with the expansion of steel manufacture, for not only are the deposits of this State unexcelled, but they are nearer great steel manufacturing centers than are the Colorado, New Mexico, and New Hampshire mines.

In 1917, Illinois produced 72 per cent and in 1918, 50 per cent of the United States total. Illinois was one of the two fluorspar shipping states out of the eight producers that reported decreased output in 1918. In Illinois this was caused by the flooding of the mines of one of the largest operators and the incompetency of the available labor in Hardin County at the time.

In the United States as a whole the average price per ton of all grades of spar at the mine was $20.72 in 1918 as compared with $10.45 in 1917, an increase of 98 per cent. Average prices in the Illinois-Kentucky district would have been even higher than they were, had not some companies continued carrying out old contracts at prices from $5 to $10 per ton. Maximum prices paid for spar for prompt delivery were in some instances $38 to $45 a ton. This rise in prices accounts for the fact that although the output was decreased 8½ per cent, the total value increased 110 per cent.

PETROLEUM AND NATURAL GAS

In August, 1859, the first oil well in the United States was drilled near Titusville, Pennsylvania, but the resultant country-wide oil fever of the 60's spread into Illinois without the discovery of anything but showings of oil at two or three places. Several wells drilled in 1865 in Parker Township, near Casey, Clark County, failed, probably because of lack of knowledge of best methods. Presumably, if proper casing had been used, salt water would have been shut off, the oil would not have been "drowned," and an earlier discovery of the southeastern fields would have been made. A second spread of oil fever during the 80's resulted in production of oil at Litchfield, of gas at Sparta, and the discovery, though not the utilization of gas, near Pittsfield. Again, in the early years of the twentieth century a wave of oil excitement encouraged drilling. In 1903 the renewed interest led to extensive drilling for the gas at Pittsfield first discovered in 1886.

During the years from 1900 to 1904 inclusive, several tests in Crawford County were made, though without success. Finally in the spring of 1904, Colonel Carter of Oakland engaged J. J. Hoblitzel and Son of Pennsylvania to drill a well on the Young farm in Parker Township, Clark County, where earlier prospecting in 1865 had revealed good showings. Although oil was found the well was not pumped, but instead the gas was used for drilling a second well near by which produced 35 barrels of oil. About 100 square miles was being drilled in Clark County in 1905 as a result of these two wells, of which about sixty square miles proved productive. Invigorated by Clark County success, prospecting was renewed in Crawford County with the result that a 250-barrel well was completed in 1906 on the Shire farm near Robinson, in Oblong Township. This well was the predecessor of the thousands of successful wells which soon gave to Illinois third rank in the United States in oil production. To date about 300,000,000 barrels of oil have been taken from the Lawrence-Crawford-Clark county fields and although production is now on the decrease, it is probable

TABLE 30.—*Domestic fluorspar sold in the United States, 1914-1918, including statistics of production for Illinois*

State	Gravel			Lump			Ground			Total		
	Quantity (short ton)	Value	Average price per ton	Quantity (short ton)	Value	Average price per ton	Quantity (short ton)	Value	Average price per ton	Quantity (short ton)	Value	Average price per ton
1914												
Illinois, Kentucky	77,048	$397,913	$5.16	8,842	$74,708	$8.45	6,998	$82,428	$11.78			
Illinois										73,811	$426,063	$5.77
Kentucky										19,077	128,986	6.76
Other States *a*	*b* 2,228	*b* 14,992	6.73	(*b*)	(*b*)	....	....	....	....	2,228	14,992	6.73
	b 79,276	*b* 412,905	5.21	*b* 8,842	*b* 74,708	8.45	6,998	82,428	11.78	95,116	570,041	5.99
1915												
Illinois, Kentucky	112,769	547,415	4.85	12,033	90,337	7.51	10,757	116,161	10.80	135,559	753,913	5.56
Other States *a*	*b* 1,382	*b* 10,562	7.64	(*b*)	(*b*)	....	....	....	....	1,382	10,562	7.64
	b 114,151	*b* 557,977	4.89	*b* 12,033	*b* 90,337	7.51	10,757	116,161	10.80	136,941	764,475	5.58
1916												
Illinois, Kentucky	123,983	660,714	5.33	14,489	114,993	7.94	7,595	94,039	12.38	146,067	869,746	5.95
Other States *a*	*b* 9,668	*b* 52,908	5.47	(*b*)	(*b*)	....	....	....	....	9,668	52,908	5.47
	b 133,651	*b* 713,622	5.34	*b* 14,489	*b* 114,993	7.94	7,595	94,039	12.38	155,735	922,654	5.92
1917												
Colorado	11,140	94,365	8.47	5,964	102,268	17.15	....	....	....	17,104	196,633	11.50
Illinois, Kentucky				19,584	247,192	12.62	10,136	178,342	17.59			
Illinois	136,954	1,111,348	8.11							156,676	1,373,333	8.77
Kentucky	33,641	534,017	15.87							43,639	697,566	15.98
Other States *a*	*b* 1,409	*b* 20,190	14.33	(*b*)	(*b*)	....	....	....	....	1,409	20,190	14.33
	b 183,144	*b* 1,759,920	9.61	*b* 25,548	*b* 349,460	13.68	10,136	178,342	17.59	218,828	2,287,722	10.45
1918												
Arizona	....	....	....	364	5,537	15.21	....	....	....	364	5,537	15.21
Colorado	32,680	287,620	8.80	5,795	129,160	22.29	....	....	....	38,475	416,780	10.83
Illinois, Kentucky				9,518	260,948	27.42	8,752	273,203	31.22			
Illinois	122,721	2,565,394	20.90							132,798	2,887,099	21.74
Kentucky	79,411	1,856,739	23.38							87,604	2,069,185	23.62
New Mexico, Other States *a*	*b* 1,309	*b* 25,507	19.49	*b* 3,267	*b* 61,373	18.79	....	....	....			
New Mexico										3,437	64,348	18.72
Other States *a*										1,139	22,532	19.78
	b 236,121	*b* 4,735,260	20.05	*b* 18,944	*b* 457,018	24.12	8,752	273,203	31.22	263,817	5,465,481	20.72

a 1914: Colorado and New Hampshire; 1915: Colorado, New Hampshire, and New Mexico; 1916: Arizona, Colorado, and New Hampshire; 1917: Arizona and New Hampshire; 1918: New Hampshire, Utah, and Washington.
b Some lump spar is included with gravel.

TABLE 31.—*Marketed production of petroleum in Illinois, 1889-1918*

Year	Marketed production	Percentage of total U. S. production	Increase or decrease		Value	Yearly average price per barrel
			Barrels	Per cent		
1889	1,460	....	....	....	$ 4,906	$3.360
1890	900	....	− 560	− 38.36	3,000	3.333
1891	675	....	− 225	− 25.00	2,363	3.500
1892	521	....	− 154	− 22.81	1,823	3.500
1893	400	....	− 121	− 23.22	1,400	3.500
1894	300	....	− 100	− 25.00	1,800	6.000
1895	200	....	− 100	− 33.33	1,200	6.000
1896	250	....	+ 50	+ 25.00	1,250	5.000
1897	500	....	+ 250	+ 100.00	2,000	4.000
1898	360	....	− 140	− 28.00	1,800	5.000
1899	360	....	....	....	1,800	5.000
1900	200	....	− 160	− 44.44	1,000	5.000
1901	250	....	+ 50	+ 25.00	1,250	5.000
1902	200	....	− 50	− 20.00	1,000	5.000
1903	....	....	− 200	− 100.00	....	....
1904	....	....	....	....	....	....
1905	181,084	0.13	+ 181,084	....	116,561	.644
1906	4,397,050	3.47	+ 4,215,966	+ 2,328.18	3,274,818	.745
1907	24,281,973	14.62	+ 19,884,923	+ 452.23	16,432,947	.677
1908	33,686,238	18.87	+ 9,404,265	+ 38.73	22,649,561	.672
1909	30,898,339	16.87	− 2,787,899	− 8.28	19,788,864	.640
1910	33,143,362	15.82	+ 2,244,923	+ 7.27	19,669,383	.593
1911	31,317,038	14.21	− 1,826,224	− 5.51	19,734,339	.639
1912	28,601,308	12.83	− 2,715,730	− 8.67	24,332,605	.851
1913	23,893,899	9.62	− 4,707,409	− 16.45	30,971,910	1.296
1914	21,919,749	8.25	− 1,974,150	− 8.26	25,426,179	1.160
1915	19,041,695	6.77	− 2,878,054	− 13.13	18,655,850	.980
1916	17,714,235	5.89	− 1,327,460	− 6.97	29,237,168	1.650
1917	15,776,860	4.70	− 1,937,375	− 10.94	31,358,069	1.988
1918	13,365,974	3.76	− 2,410,886	− 15.28	31,230,000	2.337

that these same fields will yield almost this same amount before they are completely exhausted.

The opening of the southeastern fields stimulated drilling in many parts of the State. In 1907 and 1908 tests at Sparta met with success to the extent of six or seven wells, the largest of which had an initial production of about 100 barrels. The field is now exhausted, however. In 1909 and 1910 drilling in the vicinity of Centralia and Sandoval opened up a small but good field which is still producing. About the same time small gas fields with a little oil were opened at Carlinville and Jacksonville, and a little later, in 1911, a small oil field was developed at Carlyle. The Colmar-Plymouth oil field

TABLE 32.—*Record of natural gas industry in Illinois, 1906-1918*

Year	Number of producers	Volume (M cubic feet)	Number of consumers		Value of gas consumed	Wells		
						Drilled		Productive Dec. 31
			Domestic	Indust'l		Gas	Dry	
1906......	66	409,556	1,429	2	$ 87,211	....	....	200
1907......	128	1,154,344	2,126	61	143,577	94	41	283
1908......	185	4,978,879	[a]7,377	[a]204	[a]446,077	121	42	400
1909......	194	8,472,860	[a]8,458	[a]518	[a]644,401	56	11	423
1910......	207	6,723,286	[a]10,109	[a]261	[a]613,642	64	31	458
1911......	225	6,762,361	[a]10,078	[a]293	[a]687,726	69	78	458
1912......	223	5,603,368	[a]10,691	[a]212	[a]616,467	56	147	453
1913......	231	4,767,128	[a]10,423	[a]279	[a]574,015	60	119	455
1914......	235	3,547,841	[a]8,952	[a]153	[a]437,275	38	114	417
1915......	221	2,690,593	[a]8,610	[a]134	[a]350,371	28	67	378
1916......	218	3,533,701	[a]14,485	[a]121	[a]396,357	36	126	343
1917......	225	4,439,016	[a]11,622	[a]118	[a]479,072	18	58	287
1918......	186	4,473,018	[a]8,669	[a]90	[a]620,949	11	21	254

[a]Includes number of consumers and value of gas consumed in Vincennes, Indiana.

(1914), the Staunton gas field (1915), the small Spanish Needle Creek oil field (1916), and the Ava gas field (1917) have also helped swell the State production, but unless new fields in large number or of large capacity are discovered to offset the natural decline of present producing areas, the decline will continue without break. For the time being, however, the oil and gas industry in Illinois is of major importance, as statistics for 1917 and 1918 show. Of natural gas the State produced almost four and one-half billion cubic feet, valued at almost $500,000, while of petroleum it produced more than 13,000,000 barrels, valued at more than $31,000,000. Indisputable testimony to the excellence of Illinois oil is the fact that for some years its value has kept it one notch higher in the scale of states based on total value of production than it is on the basis of quantity produced.

The enormous risk of capital involved in oil and gas prospecting and the great cost of pipe lines and refining plants make it clear that the petroleum industry does not belong to a frontier civilization, and helps to show why even slight development was delayed till 1882 and maximum productiveness until 1904, near the close of the hundred years succeeding the admission of Illinois to statehood.

More detailed information as to the development of petroleum resources in Illinois during 1917 and 1918 are to be found elsewhere in Survey publications.[1]

MODERN PERIOD, 1893-1918

Silica (tripoli), mineral paints, pyrite, sulphuric acid, asphalt, and natural-gas gasoline comprise the list of industries which had their begin-

ning in the years between 1893 and 1918. These industries are all ones which either required large capital for their development, or else depended on other industries for their existence. In this connection, it will be well to recall that the revolutionizing of three of the old and very important industries of the State came during this period and for much the same reasons as have been given above: the small early phase of the coke industry based on local coal and beehive ovens gave way to the enormous present-day industry of coking coal shipped in from the east in great batteries of by-product ovens located in the northeast part of the State; the extinct early iron industry that reduced Illinois ore was brought to life again using iron ore shipped from the Lake Superior region, as a huge industry employing thousands of men, occupying modernly equipped plants, acres in extent; and the early cement industry, which developed the natural cement deposits was overshadowed by a prodigiously greater Portland cement industry, requiring massive equipment and large production if it is to exist profitably at all.

The statements as to the mineral industries developed in the modern period will be brief.

SULPHURIC ACID

Sulphuric acid produced in Illinois is a by-product of zinc smelting at La Salle, Peru, Collinsville, and Danville, in which process the waste gases, sulphur dioxide and sulphur trioxide, are converted into acid. A product which as waste would be extremely harmful, is thus turned to good account, its value in 1918 amounting to several million dollars. Geographic and geologic conditions have combined to locate the industry at the four towns mentioned—zinc ore is shipped from other states to these points because of the abundance of coal and the adequacy of transportation.

Most of the acid finds its use in the manufacture of fertilizers; the refining of petroleum products; the iron, steel, and coke industries; the manufacture of nitrocellulose, nitroglycerine, celluloid, etc.; and general metallurgic and chemical practice.

ASPHALT

Asphalt is another by-product which swells the total of Illinois' mineral values by more than a million dollars annually. The figure includes only asphalt obtained in refining oil, not taking into account the far larger quantities produced in Illinois refineries working oil from the southwestern states. Road oil and flux are the principal uses of asphalt.

MINERAL PIGMENTS

In 1918 lead and zinc pigments were made in Illinois at Collinsville, East St. Louis, Chicago, and Argo, but only at Collinsville was pigment made directly from the ore. Again geologic and geographic conditions, as

[1]Oil Investigations in Illinois, 1917 and 1918: Ill. State Geol. Bull. 40, 1919.

expressed in abundance of coal and in adequate transportation from the lead and zinc mines outside the State, have determined the location of the industry.

TRIPOLI

Tripoli is a form of silica which finds varied uses as a paint, wood filler, metal polish, in soaps, cleansers, glass and pottery manufacture, and for facing foundry molds. The large deposits of Union and Alexander counties have been worked more or less extensively for the past twenty years and from them has come more than half of the United States production. The amount produced annually varies considerably, but the value for 1918, $100,-126, is not below the average.

Table 33.—*Tripoli produced and sold in the United States, 1917-1918*

State	1917			1918		
	Quantity (short tons)	Value		Quantity (short tons)	Value	
		Estimated (crude)	As sold (crude and finished)		Estimated (crude)	As sold (crude and finished)
Illinois	16,133	$31,338	$207,738	12,004	$18,902	$100,126
Missouri, Oklahoma and Pennsylvania	9,936	61,078	130,450	7,978	34,913	99,728
	26,069	$92,416	$338,188	19,982	$53,815	$199,854

PYRITE

Somewhat younger than the tripoli is the pyrite industry (Table 34), dating from about 1907, so far as statistics show. Especially in Vermilion County, where production was almost 100 per cent of the State's total, is the industry developed, since the pyrite can be easily saved incidental to coal mining, as it occurs in the coal of this district in distinct lenses and bands instead of being finely disseminated throughout the coal as it is in most parts of the State. That 24,369 tons worth $85,659 were marketed in 1918 shows the possibilities of an industry that is merely incidental. Pyrite is used in the manufacture of sulphuric acid, a product of great importance at all times, but especially necessary in war time.

PEAT

So uneven was the surface of the drift sheet spread over Illinois by glacial ice, that a large percentage of the northern half of the State was in its original state very poorly drained. Beds of peat were formed in the marshes, bogs, and swamps and were originally widespread in northern Illinois, notably in the Kankakee marshes, in Lee and Whiteside counties along Green River, and locally along Illinois River. Of recent years artificial drainage has been developed so rapidly in the course of reclamation of the swamp lands for agricultural purposes, that most of the beds which were

TABLE 34.—*Production in long tons and value of pyrite mined in Illinois, 1909-1918*

Year	Quantity	Value	Average price per ton
1909	5,600	$17,551	$2.60
1910	8,541	28,159	3.30
1911	17,441	47,020	2.70
1912	27,008	62,980	2.33
1913	11,246	31,966	2.84
1914	22,538	59,079	2.62
1915	14,849	22,476	1.51
1916	20,482	51,432	2.51
1917	24,596	89,998	3.66
1918	24,369	85,659	3.52

still in good condition twenty or thirty years ago have so deteriorated as to no longer have value as peat. Of course the draining of the bogs and subsequent decay of the peat results in the formation of rich soil, the tillage of which gives greater ultimate value than would development of the peat as such.

However, at two locations in the State conditions have been deemed to warrant exploitation of the peat as a source of fertilizer and stock feed. Near Manito, Mason County, the Wiedmer Chemical Company has been successfully working a large deposit since 1905; and near Sollars, Whiteside County, the American Peat Products Company has been commercially working a ten-acre tract in the Cattail Valley, a streamless depression which, leaving the Mississippi Valley southeast of Fulton, passes southeast to Rock River Valley. The Cattail Valley is underlain by peat which attains a maximum thickness of 25 to 30 feet in places.[1]

NATURAL-GAS GASOLINE

The youngest mineral industry to attain real importance in the State is the extraction of gasoline from natural gas. The story of the industry, especially the rapidity of its rise, is best told in the accompanying table. Just so long as natural gas production remains large, the industry will thrive, for it is on a sound basis in that it represents a means of turning what would otherwise be wasted into a valuable product. Those who developed the process deserve great credit for their work, for it is helping to bring about true conservation of the resource.

The decline in 1918 (Table 35) is indicative of what may be expected for the future of this industry—as natural gas production decreases, the production of gasoline from natural gas will become proportionally less. In the meantime, however, values are still so high—4,574,565 gallons valued

[1]Carman, J. Ernest, The Mississippi valley between Savanna and Davenport: Ill. State Geol. Survey Bull. 13, p. 86, 1909.

TABLE 35.—*Production of gasoline from natural gas in Illinois, 1913-1918*

	1913	1914	1915	1916	1917	1918
Number of plants..........	12	14	16	32	55	72
Quantity..............*gal.*	581,171	1,164,178	1,035,204	2,260,288	4,934,009	4,574,565
Value....................	$67,106	$100,331	$80,049	$262,664	$866,033	$890,436
Price per gallon........*cents*	11.54	8.62	7.73	11.58	....	....
Gas used..........*M cu. ft.*	160,304	462,321	552,054	1,338,594	2,685,895	2,316,646
Average yield per Mcu. ft. *gal.*	3.63	2.52	2.29	1.69	1.84	1.97

at $890,436—that this youngest industry of all is one of no mean importance.

Industries of the Future

It is not to make a prophecy about the growth of established industries that this section in the future is included, but merely to mention certain resources which seem on the way to development at the present time.

A fuller's earth deposit (see page 336) at Olmsted is receiving favorable attention from an oil company as a possible source of this material for use in its refineries.

Production of barite, which mineral is found associated with fluorspar in Hardin County[1], has been contemplated by one company for several years The mineral if marketed will probably find its chief use as a mineral pigment.

Potash in large quantities may be recovered as by-products in blast furnace and cement plant operation, a possibility which is receiving general consideration at the present time.[2]

The Mountain Glen shale of Union County (see page 310) and the Decorah shale of Lee County have possibilities as sources of potash, especially if satisfactory processes of extraction or better methods of use can be developed.[3] Attention might well be called to the fact here that where a choice is to be had, a shale high in potash is better for use in Portland cement manufacture because of the possibility of obtaining the potash as a profitable by-product.

Comparison of the Earlier-Developed Mineral Resources with Those of Later Years

It is readily recognized that the nine mineral industries which have originated in Illinois during the fifty years since 1868 differ greatly in character from those industries originated in the earlier half of the century. Every one of them is an industry requiring at least one of the following factors for its development: large population to afford market, adequate transportation facilities, an advanced stage in the manufacturing industry,

[1]Weller, Stuart, and others; Geology of Hardin County and the adjoining part of Pope County: Ill. State Geol. Survey Bull. 41, p. 254, 1920.

[2]Hicks, W. B., Potash: U. S. Geological Survey Mineral Resources of the United States, 1918, Pt. II, pp. 406-408, 1921.

[3]Austin, Parr, Krey, and Stewart, Potash shales of Illinois; University of Illinois Agricultural Exp. Station Bull. 232, 1921.

or abundant capital for establishment and upkeep. Clearly none of them could be a frontier industry. The contrast presented by the earlier group in comparison with the later is, then, a strong one: on the one hand, the older industries, though now no longer of frontier character, were developed under frontier conditions and persisted through the frontier period, proving their adaptability to such conditions; and, on the other hand, the younger industries were not adapted to and could not have been established in pioneer times. The older industries were, very logically, the development of mineral resources necessary to the simplest forms of living in a frontier country, having to do with fuel and structural materials; the younger industries involved the development of resources necessary only to a higher civilization and possible only after frontier conditions had disappeared.

ILLINOIS' MINERAL RESOURCES AND THE WAR

A final word in regard to the response of Illinois to demands placed on mineral resources of many kinds by the war may be pertinent. The remarkable increase in production along many lines in 1916, 1917, and 1918, offers general evidence. The end of the production curve for coal presents a picture of what happened in those years not only in coal but in aggregate mineral industry as well, but a few specific instances will show this in greater detail.

Even before the United States entered the war two Illinois industries, fluorspar and clay, were directly affected by the stoppage of German trading. Before the war the whole supply of clear, colorless, flawless pieces for optical instruments for scientific work passed through the hands of German optical dealers, and its stoppage promised to be a serious matter. At once, however, Illinois producers and the country's optical manufacturers were informed of the need and of the source of supply in Hardin County,[1] and the danger was averted.

The cutting off of certain German refractory clays directed attention to deposits in southwestern Illinois, and geologists and ceramic engineers soon found that one variety of Union County clay was even superior to that formerly sought in Germany. And so another gap was stopped.

Almost immediately upon our entrance into the war the small fleet of ships plying between Spain and the United States and bringing back quantities of pyrite from the rich Spanish deposits were arbitrarily transferred to service more essential to the winning of the war. Since pyrite is a source of sulphuric acid, which is not only vital to industry in general but to manufacture of explosives in particular, at first glance the action of the Government seems a strange step. But the administration, knowing well that adequate supplies existed undeveloped in this country, rightly surmised that producers would rise to meet the need. Furthermore, zinc smelting was

[1] Pogue, Joseph E., Optical fluorite in southern Illinois: Ill. State Geol. Survey Bull. 38, pp. 419, 1917.

revived in connection with war manufacture and the sulphuric acid by-product of this process was bound to increase in quantity. In both phases of the increase Illinois had a part, for the zinc smelters of the State increased their production, and coal operators took advantage of the opportunity to save pyrite, hitherto considered only as a waste; thus they increased their earnings while mining a cleaner, better coal and supplying a raw material without whose manufactured product our part of the war could not have been effectively carried on.

Another effort to conserve was the attempt to substitute Illinois, Indiana, and western Kentucky low-sulphur coals wholly or in part for coal and coke from the east, hitherto used exclusively in the important coal- and water-gas industry. Curtailment of the eastern supply by order of the United States Fuel and Railroad administrations was directly responsible for the attempt, but it is probable that experiments and investigations begun with the aid of gas engineers and geologists will continue, with the eventual result of a permanent decrease in the dependence of Illinois on the east, and a proportionate saving of energy in transportation of coal and coke from Pennsylvania and West Virginia.

The most phenomenal increase in production was that of coal, and the work of Illinois miners deserved the high praise granted it by the Fuel Administration, for not infrequently when other states were behind in their apportionments, Illinois had enough and to spare. There is no need to mention the important effect adequate fuel production has on power to increase manufactures that they may stand the strain of excessive war-time production. A fitting climax, indeed, to the first century of mineral production in Illinois is found in the realization that the mineral industries of the State did not fail to play their full part in successful prosecution of the war.

BIBLIOGRAPHY

It is believed that the following bibliography will be of help to many desiring information in regard to the mineral industries of the State, as numerous requests are received daily by the Survey for such references as are here given.

COAL[1]

Preliminary report on organization and method of investigations: Ill. Coal Mining Investigations Bull. 1, 1913.

Andros, S. O., Coal mining practice in District VIII (Danville): Ill. Coal Mining Investigations Bull. 2, 1913.

——— Coal mining practice in District VII (southwestern Illinois): Ill. Coal Mining Investigations Bull. 4, 1914.

[1]For other publications on Illinois coal and related problems see bulletins and circulars of the Engineering Experiment Station and the Mining Department described in the List of Publications of the University of Illinois.

——— Coal mining practice in District I (Longwall): Ill. Coal Mining Investigations Bull. 5, 1914.

——— Coal mining practice in District V (Saline and Gallatin counties): Ill. Coal Mining Investigations Bull. 6, 1914.

——— Coal mining practice in District II (Jackson County): Ill. Coal Mining Investigations Bull. 7, 1914.

——— Coal mining practice in District VI (Franklin, Jackson, Perry, and Williamson counties): Ill. Coal Mining Investigations Bull. 8, 1914.

——— Coal mining practice in District III (western Illinois): Ill. Coal Mining Investigations Bull. 9, 1915.

——— Coal mining practice in District IV (central Illinois): Ill. Coal Mining Investigations Bull. 12, 1915.

——— Coal mining in Illinois: Ill. Coal Mining Investigations Bull. 13, 1915.

Bement, A., Illinois coal field: Ill. State Geol. Survey Bull. 16, p. 182, 1910.

Cady, G. H., Geology and coal resources of West Frankfort quadrangle: Ill. State Geol. Survey Bull. 16, p. 242, 1910.

——— Coal resources of District I (Longwall): Ill. Coal Mining Investigations Bull. 10, 1914.

——— Coal resources of District VI (Franklin, Jefferson, and Williamson counties): Ill. Coal Mining Investigations Bull. 15, 1916.

——— Coal resources of District II (Jackson County): Ill. Coal Mining Investigations Bull. 16, 1917.

——— Geology and mineral resources of the Hennepin and La Salle quadrangles: Ill. State Geol. Survey Bull. 37, 1919.

——— Mines producing low-sulphur coal in the central district: Ill. Coal Mining Investigations Bull. 23, 1919.

——— Low-sulphur coal in Illinois: Ill. State Geol. Survey Bull. 38, p. 432, 1922.

DeWolf, F. W., Coal investigations in the Saline-Gallatin field: Ill. State Geol. Survey Bull. 8, p. 121, 1907.

——— Coal investigations in Saline and Williamson counties: Ill. State Geol. Survey Bull. 8, p. 230, 1907.

Kay, F. H., Coal resources of District VII (southwestern Illinois): Ill. Coal Mining Investigations Bull. 11, 1914.

——— Coal resources of District VIII (Danville): Ill. Coal Mining Investigations Bull. 14, 1915.

Lee, Wallace, Coal in Gillespie and Mount Olive quadrangles: Ill. Coal Mining Investigations Bull. 30, p. 51, 1917.

Parr, S. W., Purchase and sale of coal under specifications: Ill. State Geol. Survey Bull. 29, 1914.

——— Chemical study of Illinois coal: Ill. Coal Mining Investigations Bull. 3, 1915.

Savage, T. E., Geology and coal resources of the Herrin quadrangle: Ill. State Geol. Survey Bull. 16, p. 266, 1910.

——— Geology and mineral resources of the Springfield quadrangle: Ill. State Geol. Survey Bull. 20, p. 97, 1915.

——— Geology and mineral resources of the Canton and Avon quadrangles: Ill. State Geol. Survey Bull. 38, p. 209, 1921.

——— and Udden, J. A., Geology and mineral resources of the Edgington and Milan quadrangles: Ill. State Geol. Survey Bull. 38, p. 115, 1921.

Shaw, E. W., Geology and coal resources of the Murphysboro quadrangle: Ill. State Geol. Survey Bull. 16, p. 286, 1910.

———— and Savage, T. E., U. S. Geological Survey Geol. Atlas, Murphysboro-Herrin folio (No. 185), 1912.

———— ———— U. S. Geological Survey Geol. Atlas, Tallula-Springfield folio (No. 188), 1913.

Udden, J. A., Geology and mineral resources of the Peoria quadrangle: U. S. Geological Survey Bull. 506, 1912.

———— and Shaw, E. W., U. S. Geological Survey Geol. Atlas, Belleville-Breese folio (No. 195), 1915.

Young, C. M., Percentage of extraction of bituminous coal with special reference to Illinois conditions: Ill. Coal Mining Investigations Bull. 100, 1917.

Young, L. E., Surface subsidence in Illinois resulting from coal mining: Ill. Coal Mining Investigations Bull. 17, 1916.

———— and Stoek, H. H., Subsidence resulting from mining: Ill. Coal Mining Investigations Bull. 91, 1916.

GAS AND COKE

Cady, G. H., Mines producing low-sulphur coal in the central district: Ill. Coal Mining Investigations Bull. 23, 1919.

Dunkley, W. A., and Odell, W. W., The manufacture of retort coal-gas in the central district using low-sulphur coal from Illinois, Indiana, and western Kentucky: Ill. Coal Mining Investigations Bull. 21, 1918.

———— ————, Water-gas operating methods with central district bituminous coal as generator fuel, a summary of experiments on a commercial scale: Ill. Coal Mining Investigations Bull. 24, 1919.

Odell, W. W., and Dunkley, W. A., Water-gas manufacture with central district bituminous coals as generator fuel: Ill. Coal Mining Investigations Bull. 22, 1918.

Ovitz, F. K., Carbonization of Illinois coal in inclined gas retorts: Ill. Coal Mining Investigations Bull. 20, 1918.

———— Coking of Illinois coals: U. S. Bureau of Mines Bull. 138, 1917.

PETROLEUM AND NATURAL GAS

Blatchley, Raymond S., Oil resources of Illinois: Ill. State Geol. Survey Bull. 16, p. 42, 1910.

———— Oil and gas in Crawford and Lawrence counties: Ill. State Geol. Survey Bull. 22, 1913.

———— Plymouth oil field: Ill. State Geol. Survey Bull. 23, p. 51, 1917.

———— Oil and gas in Bond, Macoupin, and Montgomery counties: Ill. State Geol. Survey Bull. 28, 1914.

Brokaw, A. D., Parts of Saline, Johnson, Pope, and Williamson counties: Ill. State Geol. Survey Bull. 35, p. 19, 1917.

Butts, Charles, Parts of Hardin, Pope, and Saline counties: Ill. State Geol. Survey Bull. 35, p. 75, 1917.

Hinds, Henry, Oil and gas in Colchester and Macomb quadrangles: Ill. State Geol. Survey Bull. 23, p. 45, 1917.

Kay, F. H., Carlinville oil and gas field: Ill. State Geol. Survey Bull. 20, p. 81, 1915.

———— Petroleum in Illinois in 1914 and 1915: Ill. State Geol. Survey Bull. 33, 1916.

———— Notes on the Bremen anticline: Ill. State Geol. Survey Bull. 33, 1916.

Knirk, Carl F., Natural gas in the glacial drift of Champaign County: Ill. State Geol. Survey Bull. 14, p. 272, 1910.

Lee, Walace, Oil and gas in Gillespie and Mount Olive quadrangles: Ill. State Geol. Survey Bull. 31, p. 71, 1915.

Morse, W. C., and Kay, F. H., Area south of the Colmar oil field: Ill. State Geol. Survey Bull. 31, p. 8, 1915.

——— ——— The Colmar oil field—a restudy: Ill. State Geol. Survey Bull. 31, p. 37, 1915.

Rich, J. L., Allendale oil field: Ill. State Geol. Survey Bull. 31, p. 57, 1915.

——— Oil and gas in the Birds quadrangle: Ill. State Geol. Survey Bull. 33, 1916.

——— Oil and gas in the Vincennes quadrangle: Ill. State Geol. Survey Bull. 33, 1916.

Shaw, E. W., Carlyle oil field and surrounding territory: Ill. State Geol. Survey Bull. 20, p. 43, 1915.

St. Clair, Stuart, Ava area: Ill. State Geol. Survey Bull. 35, p. 57, 1917.

——— Centralia area: Ill. State Geol. Survey Bull. 35, p. 67, 1917.

——— Parts of Williamson, Union, and Jackson counties: Ill. State Geol. Survey Bull. 35, p. 39, 1917.

Udden, J. A., and Shaw, E. W., U. S. Geological Survey Geol. Atlas, Belleville-Breese folio (No. 195), p. 14, 1915.

——— Coal deposits and possible oil fields near Duquoin: Ill. State Geol. Survey Bull. 14, p. 254, 1910.

Weller, Stuart, Anticlinal structure in Randolph County: Ill. State Geol. Survey Bull. 31, p. 69, 1915.

GASOLINE

Burrell, F. M. S., and Oberfell, G. G., The condensation of gasoline from natural gas: U. S. Bureau of Mines Bull. 88, 1915.

Kay, F. H., Petroleum in Illinois in 1914 and 1915: Ill. State Geol. Survey Bull. 33, p. 71, 1916.

CLAY AND CLAY PRODUCTS

Bleininger, A. V., Lines, E. F., and Layman, F. E., Portland cement resources of Illinois: Ill. State Geol. Survey Bull. 17, 1912.

Cady, G. H., Cement-making materials near La Salle (includes analyses of clay): Ill. State Geol. Survey Bull. 8, p. 127, 1909.

Lines, E. H., Pennsylvanian fire clays of Illinois: Ill. State Geol. Survey Bull. 30, p. 61, 1917.

Parmelee, C. W., and Schroyer, C. R., Further investigations of Illinois fireclays: Ill. State Geol. Survey Bull. 38, p. 272, 1921.

Parr, S. W., and Ernest, T. R., A study of sand-lime brick: Ill. State Geol. Survey Bull. 18, 1912.

Purdy, R. C., and DeWolf, F. W., Preliminary investigation of Illinois fire clays: Ill. State Geol. Survey Bull. 4, p. 129, 1907.

Rolfe, C. W., Purdy, R. C., Talbot, A. N., and Baker, I. O., Paving brick and paving brick clays of Illinois: Ill. State Geol. Survey Bull. 9, 1908.

Savage, T. E., Geology and mineral resources of the Canton and Avon quadrangles: Ill. State Geol. Survey Bull. 38, p. 209, 1921.

——— and Udden, J. A., Geology and mineral resources of the Edgington and Milan quadrangles: Ill. State Geol. Survey Bull. 38, p. 115, 1921.

Shaw, E. W., and Savage, T. E., U. S. Geological Survey Geol. Atlas, Murphysboro-Herrin folio (No. 185), p. 15, 1912.

——— ——— U. S. Geological Survey Geol. Atlas, Tallula-Springfield folio (No. 188), p. 12, 1913.

——— and Trowbridge, A. C., U. S. Geological Survey Geol. Atlas, Galena-Elizabeth folio (No. 200), p. 12, 1916.

St. Clair, Stuart, Clay deposits near Mountain Glen, Union County, Illinois: Ill. State Geol. Survey Bull. 36, p. 71, 1920.

Stull, R. T., and Hursh, R. K., Tests on clay materials available in Illinois coal mines: Ill. Coal Mining Investigations Bull. 18, 1917.

Udden, J. A., Geology and mineral resources of the Peoria quadrangle: U. S. Geological Survey Bull. 506, pp. 89-90, 1912.

——— and Shaw, E. W., U. S. Geological Survey Geol. Atlas, Belleville-Breese folio (No. 195), p. 14, 1915.

FLUORSPAR

Bain, H. Foster, Fluorspar deposits of southern Illinois: U. S. Geol. Survey Bull. 255, 1905.

Burchard, E. F., Methods of concentration of fluorspar: U. S. Geol. Survey Mineral Resources, 1908, pp. 609-611, 1909.

——— Mining and milling developments in the Illinois fluorspar industry: U. S. Geological Survey Mineral Resources, 1910, pp. 706-709, 1911.

Pogue, Joseph E., Optical fluorite in southern Illinois: Ill. State Geol. Survey Bull. 38, p. 419, 1918.

Ulrich, E. O., and Smith, W. S. T., The lead, zinc, and fluorspar deposits of western Kentucky: U. S. Geological Survey Prof. Paper 36, 1905.

TRIPOLI OR SILICA

Bain, H. Foster, Analyses of silica deposits of southern Illinois: Ill. State Geol. Survey Bull. 4, p. 185, 1907.

Ernest, T. R., Experiments on the amorphous silica of southern Illinois: Ill. State Geol. Survey Bull. 8, p. 147, 1907.

Savage, T. E., Lower Paleozoic stratigraphy of southwestern Illinois: Ill. State Geol. Survey Bull. 8, p. 113, 1907.

Williams, W. S., Artificial silicates with reference to amorphous silica: Ill. State Geol. Survey Bull. 14, p. 276, 1909.

LEAD AND ZINC

Bain, H. Foster, Lead and zinc deposits of Illinois: U. S. Geological Survey Bull. 225, 1904.

——— Fluorspar deposits of southern Illinois (includes discussion of lead and zinc): U. S. Geological Survey Bull. 255, 1905.

——— Zinc and lead deposits of northwestern Illinois: U. S. Geological Survey Bull. 246, 1905.

——— Zinc and lead deposits of the upper Mississippi Valley: U. S. Geological Survey Bull. 294, 1906.

Cox, G. H., Lead and zinc deposits of northwestern Illinois: Ill. State Geol. Survey Bull. 21, 1914.

——— Elizabeth sheet of the lead and zinc district of northern Illinois: Ill. State Geol. Survey Bull. 16, p. 24, 1910.

Grant, U. S., and Purdue, M. J., Millbrig sheet of the lead and zinc district of northwestern Illinois: Ill. State Geol. Survey Bull. 8, p. 335, 1911.

Shaw, E. W., and Trowbridge, A. C., U. S. Geological Survey Geol. Atlas, Galena-Elizabeth folio (No. 200), 1916.

PYRITE

Cady, G. H., The pyrite inventory of 1918: Ill. State Geol. Survey Bull. 38, p. 427, 1921.

Holbrook, E. A., The utilization of pyrite occurring in Illinois bituminous coal: Engineering Experiment Station Circular 5, 1917.

POTASH

Schroyer, C. R., Notes on potash possibilities in Illinois: Ill. State Geol. Survey Bull. 38, p. 435, 1921.

OIL SHALE

Barrett, N. O., Notes on Illinois bituminous shales including results of their experimental distillation: Ill. State Geol. Survey Bull. 38, p. 441, 1921.

Udden, Jon, and Todd, J. E., The occurrence of structural materials in Illinois: Ill. State Geol. Survey Bull. 16, p. 342, 1910.

LIMESTONE AND CEMENT

Alden, W. C., The stone industry in the vicinity of Chicago: U. S. Geological Survey Bull. 213, pp. 357-360, 1903.

Bleininger, A. V., Lines, E. F., and Layman, F. E., Portland cement resources of Illinois: Ill. State Geol. Survey Bull. 17, 1912.

Burchard, E. F., Concrete materials in vicinity of Chicago: Ill. State Geol. Survey Bull. 8, p. 245, 1907.

——— Analyses of limestone quarried in United States: U. S. Geological Survey Mineral Resources, 1911, pp. 655-697, 1912.

Cady, G. H., Cement-making materials near La Salle: Ill. State Geol. Survey Bull. 8, p. 127, 1907.

Eckel, E. C., Burchard, E. F., and others, Portland cement materials and industry of the United States: U. S. Geological Survey Bull. 522, 1913.

Shaw, E. W., and Savage, T. E., U. S. Geological Survey Geol. Atlas, Murphysboro-Herrin folio (No. 185), p. 15, 1912.

——— and Trowbridge, A. C., U. S. Geological Survey Geol. Atlas, Galena-Elizabeth folio (No. 200), p. 12, 1916.

Udden, J. A., and Shaw, E. W., U. S. Geological Survey Geol. Atlas, Belleville-Breese folio (No. 195), p. 14, 1915.

Udden, Jon, The Shoal Creek limestone: Ill. State Geological Survey Bull. 8, p. 117, 1907.

——— and Todd, J. E., The occurrence of structural materials in Illinois: Ill. State Geol. Survey Bull. 16, p. 342, 1910.

Van Horn, F. B., Limestones available for fertilizers: Ill. State Geological Survey Bull. 4, p. 177, 1907.

Weller, Stuart, The Salem limestone: Ill. State Geol. Survey Bull. 8, 1907.

LIME

Burchard, E. F., Lime: U. S. Geological Survey Mineral Resources, 1911, pt. 2, pp. 645-718, 1912.

——— and Emley, W. E., Source, manufacture, and use of lime: U. S. Geological Survey Mineral Resources, 1913, pt. 2, pp. 1509-1593, 1914.

Shaw, E. W., and Trowbridge, A. C., U. S. Geological Survey Geol. Atlas, Galena-Elizabeth folio (No. 200), p. 12, 1916.

SAND AND GRAVEL

Burchard, E. F., Glass sand of the middle Mississippi Basin: U. S. Geological Survey Bull. 285, 1906.

——— Production of glass sand, other sand, and gravel, in 1909 (includes analyses of Illinois sands): U. S. Geological Survey Mineral Resources, 1909, pt. 2, pp. 519-542, 1911.

——— Concrete materials in the Chicago district: Ill. State Geological Survey Bull. 8, p. 345, 1907.

Shaw, E. W., and Savage, T. E., U. S. Geological Survey Geol. Atlas, Tallula-Springfield folio (No. 188), p. 12, 1913.

Udden, J. A., Geology and mineral resources of the Peoria quadrangle: U. S. Geological Survey Bull. 506, p. 97, 1912.

Udden, Jon, and Todd, J. E., The occurrence of structural materials in Illinois: Ill. State Geol. Survey Bull. 16, p. 342, 1907.

THE GEOLOGY AND MINERAL RESOURCES OF THE EDGINGTON AND MILAN QUADRANGLES

By T. E. Savage and J. A. Udden

PREFACE

Recent field examinations in the area covered by this report have suggested radical changes in the assumed correlations of the coals. Meanwhile, the geological maps had been engraved and the report had been set in type for publication. Certain improvised changes in the map and report have been made but they are of necessity brief, and are not supported by a full discussion; therefore, the reader will be glad to know that a further statement is in preparation and will soon be available.

The principal coal of the Rock Island area has long been known to the trade as "Rock Island or No. 1 coal". It has many characteristics resembling those of the No. 1 bed of Fulton County, and was regarded by A. H. Worthen, the former State Geologist, as of the same age and horizon. Furthermore, plant fossils have seemed to indicate that this coal is of Pottsville age. However, H. E. Culver of the State Survey has recently found in the roof limestone of the coal at Matherville and Sherrard, numerous fossils of *Girtyina ventricosa,* which to the best of our knowledge occur only in the limestone overlying No. 6 coal. T. E. Savage, joint author in the present report, is quite confident that the coal known as No. 1 at these mines must really be No. 6, even though there may be elsewhere in the region thinner beds comparable with No. 1 of Fulton County and of Pottsville age. At his request the present report has been changed so as to recognize the new correlation.

This new evidence, together with observations by Currier, Savage, and Culver in western Illinois, suggests a marked period of erosion near the close of Carbondale time, after which No. 6 coal was deposited widespread. Evidently in places it immediately overlies various beds of the earlier Carbondale strata, and perhaps may be found directly on the Pottsville.

Further evidence and interpretation will be presented by Mr. Culver in a report on "Coal resources of District III", Illinois Mining Investigations.

F. W. DeWolf, *Chief.*

THE GEOLOGY AND MINERAL RESOURCES OF THE EDGINGTON AND MILAN QUADRANGLES

By T. E. Savage and J. A. Udden

OUTLINE

ILLUSTRATIONS

TABLES

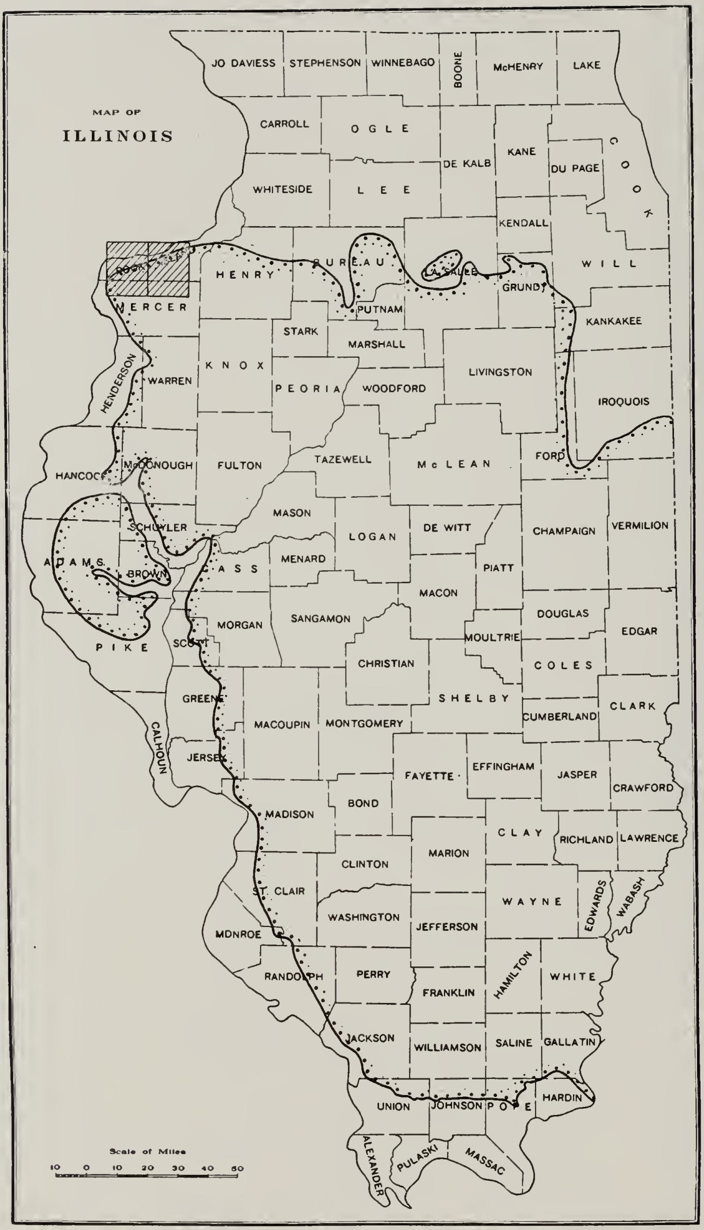


FIG. 13.—Index map showing the location of the Milan and Edgington quadrangles. The stippled boundary is the outline of the Illinois coal field.

INTRODUCTION

Position and General Relations

The Milan and Edgington quadrangles are included between the parallels 41° 15′ and 41° 30′ north latitude, and the meridians 90° 30′ and 91° west longitude. They thus embrace about one-eighth of a square degree, which at this latitude is equivalent to about 437.75 square miles. In addition to these quadrangles there is included in this report about 7 square miles lying south of the main channel of Mississippi River, and north of latitude 41° 30′. This latter tract includes the older parts of the cities of Rock Island and Moline, and the Government reservation of Rock Island, which lies between the two channels of the river. Fig. 13 is an index map showing the general position of the quadrangles.

The greater part of the area of these quadrangles is in Rock Island County, Illinois, but it also includes about 145 square miles of Mercer County, in the south part of the area, and about 60 square miles north of Mississippi River, which comprises parts of Scott and Muscatine counties, in Iowa. The principal cities in the area are Rock Island and Moline.

These quadrangles form a part of the great region known as the Glaciated Plains, which extends far to the east and west, with which this area is closely related in its physiographic and geologic history.

TOPOGRAPHY OF THE MILAN AND EDGINGTON QUADRANGLES

Relief

The surface of the Milan and Edgington quadrangles is that of a loess-covered drift plain that has been rather strongly dissected by stream erosion. In this old plain the Mississippi River and its tributary systems have carved valleys, in places one-half to 2½ miles wide, to a depth of 100 to 200 feet below the uplands. On account of the proximity of Mississippi River the extreme range of surface relief in the area is about 280 feet. The lowest place, slightly less than 540 feet above sea level, is in the valley of Mississippi River, in the northwest quarter of the Edgington quadrangle. The highest point is on the upland in the Milan quadrangle, about one mile southeast of Reynolds, where the elevation reaches 820 feet.

The area includes three distinct varieties of topographic features: upland prairies, erosion slopes, and flood plains.

Upland Prairies

The upland prairies comprise less than half the area of the quadrangles. The larger part of these uplands is included in two watersheds which extend in an east-west direction across the quadrangles, and represent the uneroded portion of the original drift-formed plain. The more northern of these divides lies between Mississippi and Rock River valleys in the north, and

Copperas and Mill creeks on the south. The second upland belt is bordered on the north by Copperas and Mill creeks and on the south by Eliza Creek and Camp Creek, and a third somewhat smaller belt of upland still farther south forms the watershed between Camp Creek and Edwards River. These upland areas are very irregular in outline. The two larger areas include a nearly continuous belt of level land one to three miles wide, extending entirely across both quadrangles. The general surface of the more northern upland belt lies between 730 and 800 feet above sea level, the highest part lying within about 5 miles east and west from the village of Edgington. The elevation of the southern area ranges from 740 to 820 feet above the sea, being higher in the Milan quadrangle, where the surface of the larger part of this belt lies above 800 feet altitude. From these main divides, inter-stream areas of varying width extend in irregular finger-like projections between the tributaries of the bordering streams, becoming progressively narrower in width and lower in altitude as the larger streams are approached.

Erosion Slopes

The valleys of Mississippi and Rock rivers are bordered by forested slopes 80 to 150 feet high. In places where the rivers have recently undercut one of their banks, a nearly perpendicular cliff of Pennsylvanian strata, 50 or more feet high, may be exposed. In other places where undercutting has not been active for a considerable period, the hard rocks are concealed by a mantle of unconsolidated material derived from slumping and sheet wash, but their presence near the surface is indicated by the steep lower slopes of the valley sides. The tributaries of Mississippi and Rock rivers, and of Edwards River, have cut valleys to the level of their master streams, and like them are bordered by rather steep slopes, a descent of 120 feet in a distance of a quarter of a mile being common. Pennsylvanian rocks are exposed in numerous places along these valleys.

One of the conspicuous features on the slopes, especially where the banks are largely composed of Pennsylvanian shale, is the slumps or landslides that have occurred on a large scale. Frequently five or six terrace-like offsets, 8 to 12 feet high and 10 to 15 rods long, are present in vertical succession on the same slope, in places where the valleys lie a considerable distance below the upland. Under such conditions slumping is one of the most important agents in the development of gentle slopes. At a considerable distance from the rivers the stream valleys are 50 to 100 feet deep, and are bounded by more gentle slopes. Toward their heads they become shallower and their slopes less steep until at length they merge insensibly into the uplands.

In the southwest part of the Edgington quadrangle, as along Eliza Creek and its branches, the banks of the streams are of Pleistocene material, and

no hard rock is exposed. Along the west border of the area the top of the bluff bordering Mississippi River is in many places capped by a deposit of wind-blown loess or sand that increases the local relief.

Flood Plains

The larger flood plains in these quadrangles are along Mississippi River, Rock River, and Edwards River. Smaller areas of alluvial deposits occur in the valleys of the larger tributary creeks.

The flood plain of Mississippi River is 3½ miles wide where the river enters the Milan quadrangle, and continues equally wide to below the junction of Rock River and Mississippi, a distance of about 4½ miles. About 3 miles east of Andalusia the bluffs converge so that the width of the flood plain does not exceed 1½ miles. The valley continues about this width to Montpelier, below which it widens to nearly 2 miles, which width it holds as far as Muscatine on the west border of the Edgington quadrangle, with the exception of a slight constriction for two miles below Fairport.

This portion of the course of Mississippi River across the Milan and Edgington quadrangles is the lower part of the "upper narrows" of the river which begins at Cordova, about 22 miles above Rock Island. In this part of its course the river was diverted from its pre-glacial channel during Pleistocene time, and has here been cutting a new, relatively narrow channel across the pre-glacial upland. Where the river bends south, at Muscatine, it enters a portion of an old pre-glacial channel, and the flood plain abruptly broadens to a width of 7 miles, which width is maintained farther southward beyond the limits of the quadrangles.

Where Rock River enters the Milan quadrangle, the flood plain is 2½ miles wide, but the width gradually decreases until at Milan it does not exceed 1½ miles. The width of the flood plain of these rivers is clearly controlled by the character of the rock that forms the bordering banks. The glacial drift has offered the least resistance to the erosional work of the streams. Rocks of Pennsylvanian age, especially the sandstones, furnish a fair degree of resistance, but the resistance of the Devonian limestones is far greater than that of either the drift or the sandstone. The narrowing of the valley of Rock River in the vicinity of Milan is clearly due to the rise of the Devonian limestone in the banks on both sides of the stream. In like manner the constriction of the valley of Mississippi River above Andalusia is also due to the presence of Devonian limestone in the valley walls. The less conspicuous narrowing of the valley of the Mississippi below Fairport was caused by the unusual thickness of Pennsylvanian sandstone in the river banks in that locality. The width of the valley of Mill Creek, in the Milan quadrangle, where it is bordered by Devonian limestone for a distance of 4 or 5 miles above the junction with Rock River, is less than one-third

of its common width farther upstream where the banks are composed of glacial drift or of Pennsylvanian shale and sandstone.

The width of the flood plain bordering Edwards River in the Milan quadrangle varies between half a mile and one mile.

The other larger streams in the quadrangles are Copperas, Camp, and Eliza creeks. These have developed flood plains throughout the greater part of their length, to a width generally less than one-fourth mile, but the larger ones are in some places nearly half a mile wide. The larger part of the flood plains of Mississippi and Rock rivers lies between 12 and 20 feet above the ordinary level of the water. The range of relief of these flood plains in the Milan quadrangle is less than 50 feet, ranging from about 560 feet above sea level near the channels of the rivers, to about 600 feet at the bases of some of the bordering bluffs. In the Edgington quadrangle the elevation of the surface of the flood plain of Mississippi River ranges from about 540 to 580 feet.

The surface of the flood plain of Mississippi River declines 15 feet in the distance of about 21 miles across the quadrangles. The principal inequalities of this river flat are broad, shallow depressions, representing partly filled channels that are followed by the flood waters. Such depressions are found northeast of New Rockingham, and also in secs. 3 and 10, South Rock Island Township, and west of Milan along Kickapoo slough. Near the main channel these depressions may contain water the most of the year, and form a network of bayous separated by sand bars or similar deposits of irregular character. Swamps and ponds are numerous over most of this valley flat.

In a few places islands of bed rock occur in the flood plain, as Rock Island on which the Government arsenal is located, and Vandruff Island in Rock River, north of Milan. However, most of the islands are formed of alluvium deposited by the river.

The thickness of the alluvial deposits along Mississippi and Rock rivers in the Milan and Edgington quadrangles usually varies from 15 to 45 feet, the rock bottom of the valley below the river lying at altitudes of from 515 to 535 feet. This slight thickness of the alluvium in the "narrows" of the river between Cordova and Muscatine is in strong contrast to the depth of alluvial deposits in the old portion of the river valley where it follows a preglacial channel (see figure 14). At Fulton, north of the "narrows," the flood-plain deposits extend downward 166 feet below the level of low water in the river, the altitude of the rock at the base of these deposits being about 400 feet above sea level. Udden[1] has reported two wells in the old channel below Muscatine that passed through about 158 feet of alluvial deposits, reaching rock at an altitude a little less than 400 feet above sea level. A well put down near the southeast corner of the Edgington quadrangle penetrated 120 feet of alluvial material without reaching bed rock.

Along the east bluff of Mississippi River north of Sears, and in the south part of Rock Island, a remnant of an old terrace extends in an almost continuous belt for 2 to 3 miles. A part of the surface of this terrace area rises above the 600-foot contour line, and the material consists mostly of cross-bedded sand and gravel. In a few other places terrace remnants appear near the bluffs where creeks leave the uplands in Buffalo, Andalusia, and Black Hawk townships.

In places where the slopes of the river banks are gentle the bottom lands rise as the bluffs are approached. This rise is doubtless due to the

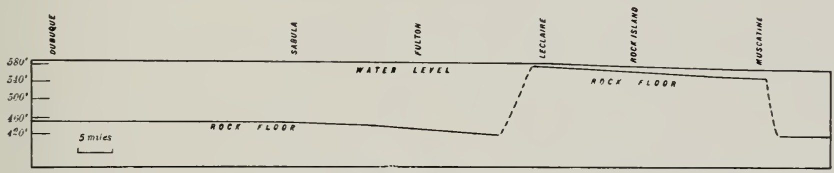


FIG. 14.—Profile of the rock bottom of Mississippi River between Dubuque and Muscatine.

deposition of sediment as sheet wash from the bordering banks, or as low, more or less coalescing alluvial fans deposited where small streams flowing down the steeper bluff slope have been unable to carry the load of sediment across the level flood plain.

DRAINAGE

All of the area included in the Milan and Edgington quadrangles belongs to the Mississippi River drainage system. The Mississippi enters at the northeast corner of the area, flows southwest to the mouth of Rock River, thence nearly west across the northwest quarter of the Milan quadrangle and the north part of the Edgington, and leaves the area in section 31, T. 17 N., R. 5 W.

The drainage basin of Mississippi River above Quincy includes about 135,500 square miles, while that portion of the basin above Moline is about 90,000 square miles. The run-off from the part of the basin above Quincy is about .538 second-feet per square mile. In this part of its course the river carries each year 108 tons of dissolved mineral matter, and 63 tons of suspended matter from each square mile of its drainage basin. At this rate more than 1,100 years are required to lower the entire surface of its drainage basin one inch, which is at the rate of one foot in from 13,000 to 14,000 years.

Rock River, the largest tributary of the Mississippi in the quadrangles, rises in Wisconsin, and flows in a southwest direction for nearly 300 miles, joining the Mississippi near the town of Milan. The drainage basin of Rock River is about 10,970 square miles, about half of which is in Wisconsin. From its source to its mouth the river falls about 340 feet, the average

[1]Udden, J. A., Reported by Leverett, U. S. Geological Survey, Mon. 38. p. 475, 1899.

slope being 1.2 feet to the mile. The greatest fall in Illinois, for any considerable distance is from Oregon to Sterling, a distance of 36 miles in which the average slope is 1.31 feet per mile. The average discharge of Rock River into the Mississippi from October 1, 1906, to July 31, 1907, was between 8,000 and 9,000 cubic feet per second. The river removes each year an average of 200 tons of mineral matter in solution and 180 tons of sediment in suspension from each square mile of its drainage basin. At this rate the level of the entire basin would be reduced one inch in 500 years, or at the rate of one foot in about 6,000 years.

Besides Rock River, the larger tributaries to the Mississippi in these quadrangles are Edwards River, and Copperas, Camp, Eliza, and Mill creeks. With the exception of Mill Creek, all of these flow in a general westerly direction, approximately parallel with the Mississippi in this area. Their channels are bordered by narrow, well-defined flood plains having an average slope of 8 to 12 feet to the mile. Mill Creek follows an easterly course throughout the greater part of its length, but bends abruptly northward about 5 miles above its mouth, and continues in this direction to its junction with Rock River a short distance east of Milan. The eastward course of Mill Creek is in a direction opposite to that of the other streams of the area, and its abrupt bend to the northward a few miles above its mouth are peculiar features for a stream in this region. The explanation is probably to be found in the irregularities in the original surface of the drift plain. The surface of the drift is now somewhat higher over the narrow divide between the headwaters of Copperas and Mill creeks than over any other part of the surface bordering the immediate valleys of these streams. This divide west of Reynolds has an elevation of 810 feet above sea level, and toward the south it merges into the watershed between Mill and Camp Creeks, on which, about a mile southeast of Reynolds, is the highest point in the quadrangles.

All of the larger streams in the quadrangles have numerous tributaries which generally are two to four miles long and are about one mile apart. They usually follow a north-south direction, and meet their major streams nearly at right angles.

CULTURE

The larger part of the surface of the quadrangles, except in the lower parts of the flood plains, is under cultivation, and agriculture is the principal industry. The area is rather thickly, though not densely, settled. The largest cities are Rock Island and Moline at the northeast corner of the Milan quadrangle. The population of Rock Island is 35,000, while that of Moline is 31,000. The smaller towns usually have only a few families, or a few hundred inhabitants. In the Milan quadrangle are Milan, Sears, Sherrard, Cable, Matherville, Reynolds, Andalusia, and Taylor Ridge in

Illinois, and the village of Buffalo in Iowa. In the Edgington quadrangle are the villages of Edgington, Illinois City, and Buffalo Prairie in Illinois, and Fairport and Montpelier on the Iowa side of the river.

There are a few commercial coal mines and several local mines in the area, but coal mining is not a very important industry in the quadrangles. Considerable manufacturing is carried on in the cities of Rock Island and Moline, and the railroads give employment to a large number of people.

The Milan quadrangle is well provided with transportation facilities, but the Edgington is less fortunate in this regard. The main line of the Chicago, Rock Island and Pacific, and the Chicago, Milwaukee and St. Paul railways pass through Moline and Rock Island, and follow the north side of the valley of the Mississippi across the north end of the quadrangles to Muscatine. The Peoria branch of the Chicago, Rock Island, and Pacific crosses the northeast quarter of the Milan quadrangle, connecting Rock Island and Peoria. The Sherrard and Cable branch of the Chicago, Rock Island and Pacific, and the Rock Island Southern Interurban connect Rock Island with most of the towns in the Milan quadrangle, and the latter continues southward to Monmouth. The wagon-roads, which are mostly dirt, follow land-survey lines and, except in the more hilly areas and over the swampy flood plains, there are few places in the quadrangles more than half a mile distant from a public road.

DESCRIPTIVE GEOLOGY

Stratigraphy

GENERAL CHARACTER OF THE ROCKS

The rocks that are exposed at the surface or have been explored in deep drillings in the Milan and Edgington quadrangles include formations ranging in age from the Cambrian to Recent time. The Cambrian, Ordovician, and Silurian strata are known in this area only from deep well explorations made for artesian water in the north part of the Milan quadrangle, where they have been penetrated to a maximum depth of 2,368 feet The Devonian, Carboniferous, and Pleistocene rocks are known both from natural outcrops and from deep borings. A generalized columnar section of all the formations known in the quadrangles is shown in figure 15.

DATA ON ROCKS NOT EXPOSED IN THE QUADRANGLES

Information regarding the rocks older than the Devonian in the Milan and Edgington quadrangles has been obtained chiefly from eight deep well borings, a summary of the records of which is given below. As these records have been previously published[1], some of the details of the logs are here omitted.

[1]Udden, J. A., Deep well borings in Illinois: Ill. State Geol. Survey Bull. 24, 1914.

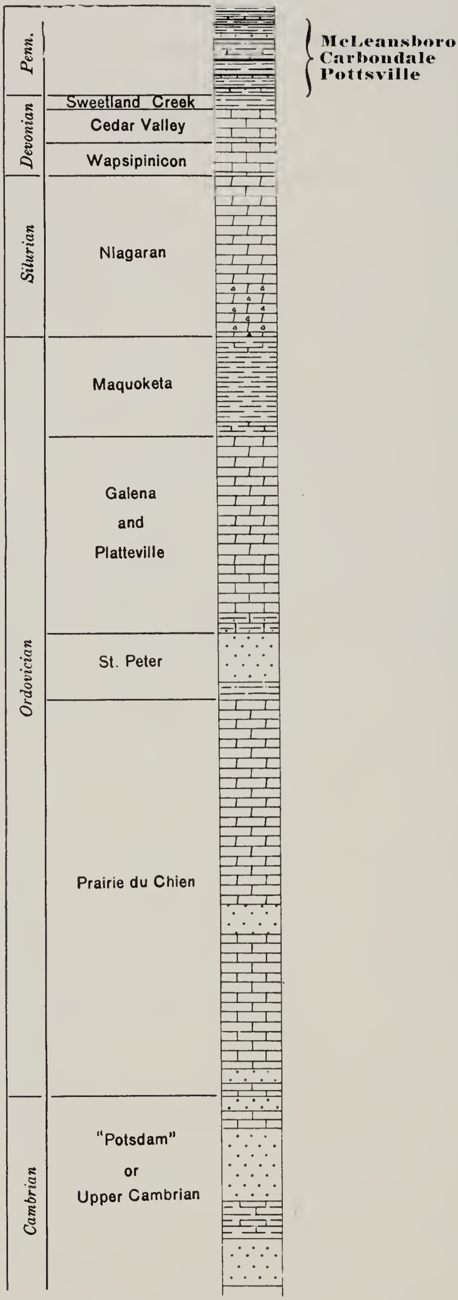


FIG. 15.—Generalized columnar section of the rocks exposed, and explored by deep borings in the Milan and Edgington quadrangles. (Scale, 1 inch=400 feet.)

RECORDS OF DEEP WELLS

The succession of strata penetrated in the well put down by the Modern Woodmen in Rock Island is as follows. The altitude of the curb is about 565 feet above mean sea level.

Log of the Modern Woodmen's well near Seventeenth Street and Third Avenue in Rock Island

Description of strata	Thickness Feet	Total depth Feet
Devonian and Silurian systems, undifferentiated—		
Limestone, samples not studied	160	160
Silurian system—		
Niagaran limestone—		
Dolomite, yellowish at the top, white in middle and lower parts, cherty near the base; molds of crinoid stems near the middle	300	460
Ordovician system—		
Maquoketa shale —		
Shale, fossiliferous in upper half, containing layers of dolomite at different levels, the lower 40 feet bituminous	170	630
Galena dolomite—		
Dolomite, coarse texture in some parts, with some chert	250	880
Platteville limestone—		
Limestone, non-magnesian, gray	85	965
Shale, green, and some sand	35	1000
St. Peter sandstone—		
Sand, quartz, in white, rounded grains	115 ?	1115 ?
Shale, green	8	1123

The deepest drilling made in the quadrangles was the well put down by the Tri-City Railway Company, in Prospect Park, in Moline. The record below 1,161 feet was furnished by J. G. Huntoon. The elevation of the top of the well is 611 feet above the sea.

Log of the Tri-City Railway Company's well in Prospect Park, Moline, near the center of the east line of sec. 8, T. 17 N., R. 1 W.

Description of strata	Thickness Feet	Total depth Feet
Quaternary and Pennsylvanian, undifferentiated—		
Boulder clay above, and shale and sandstone of Pennsylvanian age below	71	71
Devonian system—		
Middle Devonian series—		
Wapsipinicon and Cedar Valley limestones—		
Limestone, mostly compact, gray, or white, nonmagnesian	59	130
Silurian system—		
Niagaran series—		
Dolomite, straw-colored to grayish-white, and white, in places porous, and containing pockets of clay and some chert in the lower part	356	486

Log of the Tri-City Railway Company's well in Prospect Park, Moline, near the center of the east line of sec. 8, T. 17 N., R. 1 W.—Concluded

	Thickness *Feet*	Depth *Feet*
Ordovician system—		
Cincinnatian series		
Maquoketa shale		
Shale, gray and dark gray, containing fragments of brachiopods above, and bituminous material in the lower part..	235	721
Mohawkian series—		
Platteville and Galena limestones—		
Dolomite, gray and yellowish-gray, with some chert in lower part	200	921
Limestone, yellowish-gray and bluish-gray, fissile, with a little chert	130	1051
Clay, greenish-gray, with rounded grains of sand	40	1091
St. Peter sandstone—		
Sandstone, in clean rounded quartz grains	40	1131
Clay or shale, greenish-gray, pyritiferous	30	1161
Canadian series—		
Prairie du Chien limestone—		
Limestone (Shakopee)	419	1580
Sandstone, hard and soft (New Richmond)	60	1640
Limestone, hard and soft	265	1915
Limestone and shale	10	1925
Sandstone, hard and soft	30	1955
Limestone	25	1980
Cambrian system—		
"Potsdam" series—		
Sandstone	110	2090
Shale, sandy	60	2150
Limestone and shale, with salt water	50	2200
Shale, sandy	65	2265
Sandstone	103	2368

A driller's record of the strata penetrated in the deep well in the town of Milan is given below. The elevation of the curb above sea level is 566 feet.

Log of the Milan city well, located on the south bank of Rock River

Description of strata	Thickness *Feet*	Total depth *Feet*
Quaternary system—		
Pleistocene and Recent series—		
Alluvium	7	7
Devonian system—		
Middle Devonian—		
Wapsipinicon and Cedar Valley limestones—		
Limestone, white (estimated)	58	65
Silurian system—		
Niagaran series—		
Limestone, white	325	390

Log of the Milan city well, located on the South bank of Rock River—Concluded.

	Thickness *Feet*	Depth *Feet*
Ordovician system—		
Cincinnatian series—		
Maquoketa shale—		
Shale, gray	160	550
Shale, with streaks of limestone	55	605
Mohawkian series—		
Galena limestone—		
Limestone, brown	95	700
Limestone, white	140	840
Platteville limestone—		
Limestone, brownish	90	930
Shale	30	960
St. Peter sandstone—		
Sand, quartz, in rounded grains	90	1050
Limestone, sandy, or calcareous sandstone	10	1060
Sand and limestone, with some shale	35	1095
Sandstone, hard and sharp	20	1115
Marl, red	10	1125
Canadian series—		
Prairie du Chien limestone—		
Limestone, white (Shakopee dolomite)	32	1157

A log of the Mitchell and Lynde well in Rock Island, was furnished by J. H. Southwell as follows. The elevation of the curb was 558 feet above sea level.

Log of the Mitchell and Lynde well, located between East and West Seventeenth Streets, north of Second Avenue, in Rock Island

Description of strata	Thickness *Feet*	Total depth *Feet*
Devonian system—		
Limestone	60	60
Silurian system—		
Limestone (Niagaran)	276	336
Ordovician system—		
Shale (Maquoketa)	180 ?	516
Limestone (Galena)	353 ?	869
Limestone (Platteville)	90	959
Sandstone (St. Peter)	186	1145
Limestone (Prairie du Chien)	811	1956
Cambrian system—		
Sandstone, compact	30	1986
Limestone	35	2021
Sandstone	130	2151
Limestone, shaly	75	2226
Sandstone	97	2323

There is given below a record of the strata penetrated in a well drilled by the Rock Island Brewing Company in Rock Island. The elevation of the curb is 654 feet above sea level.

Log of the Rock Island Brewing Company's well, on Elm Street, near Ninth Avenue, in Rock Island

Description of strata	Thickness *Feet*	Total depth *Feet*
Quaternary and Pennsylvanian systems—		
Undifferentiated	100	100
Devonian system—		
Middle Devonian series—		
Wapsipinicon and Cedar Valley limestones—		
Limestone, gray, with some shale in the lower 20 feet	50	150
Silurian system—		
Niagaran series		
Dolomite, yellowish-brown, with cavities filled with sandy shale	375	525
Ordovician system—		
Cincinnatian series—		
Maquoketa shale—		
Shale, bluish gray	205	730
Mohawkian series—		
Galena and Platteville limestones—		
Limestone	330	1060
Shale, blue	25	1085
St. Peter sandstone—		
Sandstone, with some shale below	204	1289
Canadian series—		
Prairie du Chien limestone—		
Limestone, with some caving shale and rotten limestone (Shakopee dolomite)	315	1604
Cambrian system—		
"Potsdam" series—		
Not described	346	1950
Sandstone of various colors	207	2157

THE GENERALIZED SECTION

From a study of the well records above described, supplemented by data from some other wells in this vicinity, the general character and thickness of the underlying rocks penetrated in deep drillings, but nowhere exposed in the quadrangles, are known with a fair degree of accuracy.

Cambrian System

"POTSDAM" SERIES

In the Mitchell and Lynde well a change from dolomite to compact sandstone was reported at a depth of 1,956 feet. A similar change at the base of this dolomite was noted in the well at the Glucose Factory in Davenport, a short distance north of the Milan quadrangle. The 347 feet of rock

penetrated below the depth of 1,956 feet in the Mitchell and Lynde boring consisted of compact sandstone, 30 feet; limestone, 35 feet; sandstone, 130 feet; shaly limestone and shale, 75 feet; sandstone, 97 feet. In the well at the Glucose Factory in Davenport, the corresponding strata as far as explored were reported as follows: shale, 40 feet; sandy limestone, 20 feet; sandy rock, 160 feet; shale, 50 feet. Some of the sand in this part of the boring is said to be red. In the record of the Rock Island Brewing Company's well, on Elm Street, the strata penetrated below 1,950 feet were said to consist of "sand rock of various colors." In the log of the Tri-City Railway well in Prospect Park, in Moline, the strata beneath the Ordovician dolomites are described as follows: sand rock, 110 feet; sandy shale, 60 feet; limestone and shale with salt water, 50 feet; sandy shale, 65 feet; sand rock, 3 feet.

Ordovician System

PRAIRIE DU CHIEN LIMESTONE

The reported thickness of the Prairie du Chien limestone in the Mitchell and Lynde well is 811 feet. In the Paper Mill well in Moline 487 feet of this formation was penetrated, and 122 feet of sandstone is reported as occurring between 315 to 437 feet below the St. Peter sandstone. From samples of rock drillings from the City Park well in Davenport, which explored the upper 600 feet of this formation, some of the rock is known to consist of dolomite with more or less sand, and it also contains some green shale and some glauconite. The sandstone reported in the record of the Paper Mill well, between the depths 1,456 and 1,587 feet, is probably equivalent to the New Richmond sandstone member of the Prairie du Chien limestone.

ST. PETER SANDSTONE

The St. Peter sandstone is an important source of artesian water in northern Illinois and eastern Iowa, and it has been penetrated by almost all of the deep water wells in this region. In the most of the records of deep wells in the quadrangles a bed of shale is reported immediately above and another below the main bed of St. Peter sandstone. The normal sandstone is composed of well-rounded grains of clear quartz, remarkably free from impurities of any kind. The thickness of this formation recorded in the various logs of deep wells in the quadrangles ranges from 50 to 186 feet, the average being nearly 100 feet. The shaly material in the basal part of the formation is quite variable. In the Prospect Park well it is a green shale; in the Paper Mill well it is reported as a red marl; and in the log of the Milan city well it was described as "sand and limestone with shale and crevices," and some hard sharp sandstone resting on ten feet of red marl. The average thickness of these variable, basal, beds of the St. Peter formation, as given in the various records, is 37 feet.

The shale reported immediately above the St. Peter sandstone is greenish and probably belongs to the basal Platteville. In the Paper Mill well from which the greatest thickness of this part of the section was reported, it was said to be sandy, and contained streaks of sandstone. Elsewhere it has been found to contain rounded grains of sand and some white chert with a peculiar reticulated structure. It usually contains marcasite, and some dark and more indurated shale. In six borings in or near the quadrangles the average thickness of this shale horizon was about 40 feet.

PLATTEVILLE LIMESTONE

The rock overlying the shale above the St. Peter sandstone is a gray, non-magnesian limestone, highly fissile in the direction of its bedding planes. Some of the layers contain chert, and imbedded quartz sand grains of variable color. Fragments of bryozoa and other fossils have been noted in some of the drillings of the Platteville. Drillers usually have not reported this formation separately from the overlying Galena, but its measured thickness in four wells averaged nearly 100 feet, and ranged from 85 to 130 feet.

GALENA DOLOMITE

The Galena formation is usually a dolomite, the upper 50 feet of which is compact and light gray, below which the color changes to yellowish gray and the texture becomes more porous. The lower, yellowish rock in places contains some chert and quartz sand grains of various colors. At a level about 100 feet below the top of the formation, structures resembling spherules of oolite have been distinguished in some of the drillings. The porous portion of the Galena dolomite usually furnishes an abundant supply of water, but it is nearly always more highly charged with hydrogen sulphide gas than the water from any other deep water-bearing horizon in this region. In four wells where it has been separately measured, the thickness of the Galena ranged from 200 to 353 feet, with an average of 260 feet. In two wells where the Galena and the Platteville have not been separately measured, the average combined thickness was 395 feet. The average thickness of the Galena dolomite reported in all of the deep wells in and near the cities of Rock Island, Moline, and Davenport is about 262 feet.

MAQUOKETA SHALE

The lithologic characters of the Maquoketa shale are quite constant in the different wells in this immediate region, and certain features of lithology and texture are characteristic of certain horizons within the formation. The uppermost 120 to 150 feet of the formation consists of light greenish-gray shale, with little calcareous material, except in places near the top where fragments of calcareous shells are common, and sand is also present. A short distance below the middle of the formation the shale becomes gray

and more calcareous. At this horizon crinoid segments, bryozoa, and other fossils are usually present in greater or less numbers. Marcasite is most abundant in a zone extending from the base of this fossiliferous horizon down to within 20 feet of the base of the formation. The lower 20 to 50 feet of the Maquoketa consists of dark, in places almost black, bituminous shale, which contains a considerable amount of combustible matter. It also contains some peculiar microscopic, brownish-yellow flakes which have an irregular outline and uneven surface, and some minute irregular agglomerations of extremely small particles suggestive of flocculation in the formation of these sediments. These agglomerations occur sparingly throughout the thickness of the Maquoketa, but are most abundant in the dark shale near the base where they appear to be composed of a greater number of particles than in the gray and green shale at higher levels. Layers of dark and gray dolomite in places occur at various levels in the formation. The measured thickness of the Maquoketa in seven wells in the quadrangles ranges from 170 to 235 feet, the average being 204 feet.

Silurian System

NIAGARAN LIMESTONE

The Silurian strata in this region are dolomitic, and are of Niagaran age. The upper third of the formation is a porous, and mostly coarsely crystalline dolomite which corresponds to the phase to which the name Leclaire limestone has been applied by the Iowa geologists.[1] This phase of the Niagaran dolomite outcrops on both sides of Mississippi River a short distance above the town of Hampton, about 12 miles northeast of the Milan quadrangle. The rock contains molds of brachiopods and crinoid stems, and is yellow where exposed, although the cuttings obtained from wells are more often white and granular. The lower half of the Niagaran limestone is of finer texture, somewhat softer, and less porous than the upper part, and shows dark streaks and blotches due to oxide of manganese. In some wells very hard dolomite has been penetrated near the middle part of the Niagaran. A thickness of forty feet or less in the basal part of the Silurian limestone contains several layers of chert or flint.

The upper half of the formation is water-bearing and is the source from which many deep farm wells in the surrounding country obtain their supply of water. The Niagaran limestone has many solution caverns, most of which are filled with sand and green clay. Seven measurements of the thickness of the Niagaran limestone in the well records of these quadrangles range from 276 to 375 feet, the average being 330 feet. This variation in thickness is thought to be mostly due to an erosional unconformity between the Niagaran and the overlying Devonian limestone.

[1]Norton, W. H., Geology of Scott County, Ann. Rept. Iowa Geol. Survey, vol. IX, p. 423. 1898.

ROCKS EXPOSED IN OR NEAR THE EDGINGTON AND MILAN QUADRANGLES

Devonian System

WAPSIPINICON AND CEDAR VALLEY LIMESTONES

The Devonian rocks in the Milan and Edgington quadrangles are about 140 feet thick, and consist mostly of limestone, with some shale and some dolomite. These should all be regarded as of upper Devonian age, and represent the Wapsipinicon and Cedar Valley stages. They outcrop only

Fig. 16.—Thin-bedded limestone just below the horizon of the *Acervularia davidsoni* coral-reef horizon. The slightly overhanging layer in the upper right-hand side of the ledge is the coral reef rock. Exposure on Mill Creek near Milan.

in and near the valleys of Mississippi and Rock rivers in this region, but probably underlie the entire extent of the quadrangles. The general section of Devonian strata exposed near and within the limits of the quadrangles is given below:

Generalized section of the Devonian limestone in and near the Milan and Edgington quadrangles

	Thickness *Feet*
10. Dolomite, yellowish-gray to brown, compact, in layers ½ to 2 feet thick, alternating with thinner layers of clayey shale, containing many *Stromatoporoids, Zaphrentis sp., Stropheodonta* cf. *concava, Spirifer iowensis, S. subvaricosa, and Atrypa reticularis;* exposed along several of the creeks within a few miles both east and west of Andalusia............	20

Generalized section of the Devonian limestone in and near the Milan and Edgington quadrangles—Continued.

	Thickness *Feet*
9. Limestone, thin bedded, gray, with partings of shale; containing *Stromatoporoids, Stropheodonta demissa, Schizophoria iowensis, Athyris fultonensis, Atrypa reticularis* (large shells), *Gomphoceras* cf. *ajax,* and other fossils; exposed near the mouths of a few of the streams within 1½ miles east and west of Andalusia, and in the vicinity of Buffalo, on the north side of the river..	4
8. Dolomite, yellowish-gray, in layers 12 inches or less thick; containing *Cystodictya hamiltonensis, Stropheodonta demissa, Athyris fultonensis, Spirifer asper, Spirifer euryteines, Spirifer subvaricosus, Cyrtina hamiltonensis, Atrypa reticularis* (small shells), and other fossils..........	6
7. Limestone; the upper 1½ feet is a coral reef (fig. 16), containing a profusion of corals, and other fossils, of which *Acervularia davidsoni, A. profunda, Cystiphyllum* cf. *americanum, Favosites placenta, Alveolites goldfussi, Cladopora sp.,* and *Atrypa reticularis* are common. At the base is an organic sand or breccia which in places projects by intersecting vertical plates into the underlying layer. This bed is exposed in the bank of the river below Andalusia. On account of its resistance to weathering it forms small rapids in a number of the small creeks on the north side of the river below Linwood, and forms the capping of the Devonian outcrops above Buffalo, and in the right bank of Mill Creek near the center of sec. 25, T. 17 N., R. 2 W., where it is the highest layer of Devonian limestone exposed........................	8
6. Limestone, impure, bluish-gray, crinoidal, thin-bedded, weathering yellow; containing the fossils *Cladopora iowensis, Striatopora rugosa, Megistocrinus latus, Stropheodonta demissa, Leptostrophia perplana, Chonetes scitulus, Spirifer asper, Spirifer euryteines, Spirifer iowensis, Spirifer subvaricosus, Cyrtina umbonata,* and *Dinichthys pustulosus;* exposed at most of the localities where the overlying coral reef outcrops	5
5. Limestone, blue, argillaceous, fine grained, with oblique fracture, weathering more rapidly than the overlying or underlying strata; containing *Spirophyton* sp., *Streptelasma rectum, Stropheodonta demissa, Leptostrophia perplana, Chonetes scitulus, Spirifer iowensis, Spirifer subvaricosus, Cyrtina umbonata, Atrypa reticularis, Atrypa aspera* var. *hystrix,* and other fossils. This limestone is exposed in the abandoned quarry near the corner of Fifth Avenue and Thirty-fifth Street in Rock Island; it forms the beach of the river front in Buffalo, and outcrops in the quarries near Linwood and Buffalo, and in the banks of nearly all of the creeks north of Mississippi River, and it is the most conspicuous part of the Devonian section along Mill Creek, in sec. 25, T. 17 N., R. 2 W.	20
4. Limestone, fine grained, rather thin bedded, the layers separated by partings of greenish shale; containing the fossils *Acervularia davidsoni, Heliophyllum halli, Cystiphyllum americanum, C. sulcatum, Favosites alpenensis, Schizophoria iowensis, Pentamerella dubia, Productella sub-*	

Generalized section of the Devonian limestone in and near the Milan and Edgington quadrangles—Continued.

	Thickness Feet
alata, Spirifer asper, S. bimesialis, Cyrtina umbonata, and many other fossils. This is the upper rock formerly quarried in Rock Island, Sears, and on Mill Creek	5
3. Limestone, hard, gray, in indistinct layers ½ to 2 feet thick; containing *Astreospongia hamiltonensis, Stromatoporoids, Heliophyllum halli, Chonophyllum magnificum, Diplophyllum* cf. *archiaci, Phillipsastrea billingsi, Cystiphyllum sulcatum, Favosites alpenensis, Spirifer subundiferus, Phacops rana,* and *Dinichthys pustulosus.* This limestone outcrops near the railroad bridge across Mill Creek, and near the wagon bridges across Rock River; it is the main horizon formerly worked in the old quarries in Rock Island, and near Milan, and in the west part of Davenport, and it is exposed in several places in the north bank of the Mississippi as far west as Linwood	7

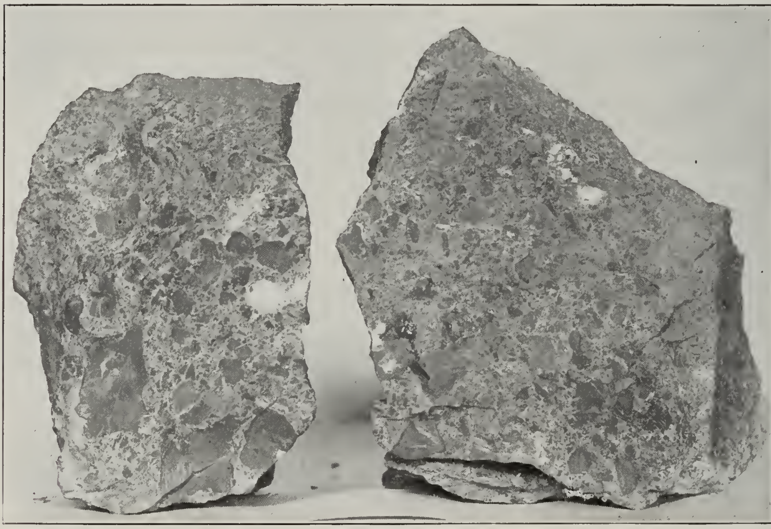


Fig. 17.—Photograph showing the character of the brecciated limestone in the basal part of the Devonian, near Rock Island, Illinois. (No. 2 of the generalized section of the Devonian limestone.)

2. Limestone, white to dark gray, fine grained, with few fossils; in layers ½ to 3½ feet thick, in places finely laminated, and showing dome-like convexities from ½ to 1 foot in diameter; usually much fractured and brecciated into fragments from 1 inch to 2 feet in diameter; worked in the Cady quarry in East Moline, and exposed in the south bank of the Mississippi in the city of Rock Island, and in the quarries around Oakdale on the north side of the river, and on Horse, Suburban, Sylvan, and Rock (Government) islands. It forms the main bed rock in the Rock River valley between Milan and Sears, and is exposed in the bed of Mill Creek near the Railroad Bridge in sec. 25, T. 17 N., R. 2 W.	50

Generalized section of the Devonian limestone in and near the Milan and Edgington quadrangles—Concluded.

	Thickness *Feet*
1. Limestone, white to yellowish gray, fine grained, not brecciated, in irregular layers some of which are porous and more or less bituminous; containing spherical concretions of chalcedonic quartz and numerous shells of *Spirifer subumbonus.* One of the layers, 1 to 2 feet thick, is crowded with shells of *Spirifer subumbonus.* This basal Devonian limestone is exposed on the east side of Campbells Island, about 4 miles northeast of the Milan quadrangle, and on the Illinois side of the river opposite this locality, and was partly explored in deepening the Sylvan channel above the Moline bridge near the east end of Rock Island (Government Island). Exposed 9 feet, estimated thickness............	20

In the south part of the Milan and in the Edgington quadrangles, several borings have pased through the Pennsylvanian rocks, and entered the Devonian limestone at depths varying usually from 150 to 250 feet; but in a few of the wells in the south part of the Milan quadrangle the depth to the top of the Devonian exceeds 300 feet. The greater depth to the limestone in this part of the area suggests that it may here be overlain by a remnant of the Sweetland Creek (Upper Devonian) shale, as it is in places in the north part of the Edgington quadrangle in Muscatine County, Iowa, and in Schuyler County and elsewhere in Illinois; but this shale is not exposed in the Illinois portion of the quadrangles.

The Devonian limestone above described falls readily into three easily distinguishable horizons, as follows:

Upper horizon:
  Dolomites and limestones, in places shaly, including numbers 8, 9, and 10 of the preceding general section.
Middle horizon:
  Limestones, mostly shaly, including numbers 3, 4, 5, 6, and 7 of the preceding general section.
Lower horizon:
  Limestone, mostly brecciated except in basal part, with few fossils, including numbers 1 and 2 of the preceding general section.

During the time of deposition of these limestones there seem to have occurred several changes in the sedimentary process. The lower group of limestones is mainly composed of a calcareous slime which may have accumulated rather rapidly. The middle group of shaly limestones (fig. 18) contains fossils which in places in the lower half are worn and more or less etched, and may represent levels of corrasion by submarine currents. The upper part of this group consists of crinoidal limestone deposited in quiet waters where even the delicate arms and calyx portions of large crinoids could be occasionally imbedded, and thus become preserved. These quiet conditions of crinoid growth were followed rather abruptly by widespread

coral growth in such numbers that the accumulation of their hard parts formed a coral reef (fig. 16) over all of this region, constituting the basal member of the upper group. The thickness of the Devonian is different in different parts of the quadrangles, partly on account of the erosional uncomformity both above and below it, and partly as a result of the general dip toward the southwest of about 6 feet to the mile. West of Oakdale the southwestward dip is more than 12 feet per mile. The average slope of the upper surface of the Devonian is about 9 feet to the mile in a nearly southward direction. This difference in the direction of slope of the old erosion plane, and of the dip, indicates that the limestone is thickest in the southwest part of the area, and thins toward the northeast.

FIG. 18.—Shaly limestone in the middle part of the Devonian section, along Mill Creek, near Milan, Illinois.
(No. 5 of the generalized section of the Devonian limestone.)

In the country east of the junction of the Mississippi and Rock rivers, the pre-Pennsylvanian erosion of the Devonian removed all of the upper group and most of the middle one, while west of this junction probably all of the middle group, and nearly all of the upper one is usually present.

SWEETLAND CREEK SHALE

The Sweetland Creek shale (fig. 19) is brown to black in color, and contains numerous spores of a fern-like plant called *Sporangites huronense.* This shale is well exposed in the bed and banks of Sweetland Creek, in secs. 22 and 27, T. 77 N., R. 1 W., and in a few other places north of Mississippi River in the Edgington quadrangle. A brown shale ranging from

a few feet to thirty feet thick was reported immediately above the Devonian limestone in the driller's logs of a number of coal-test borings in Buffalo Prairie Township. This shale is thought to represent the Upper

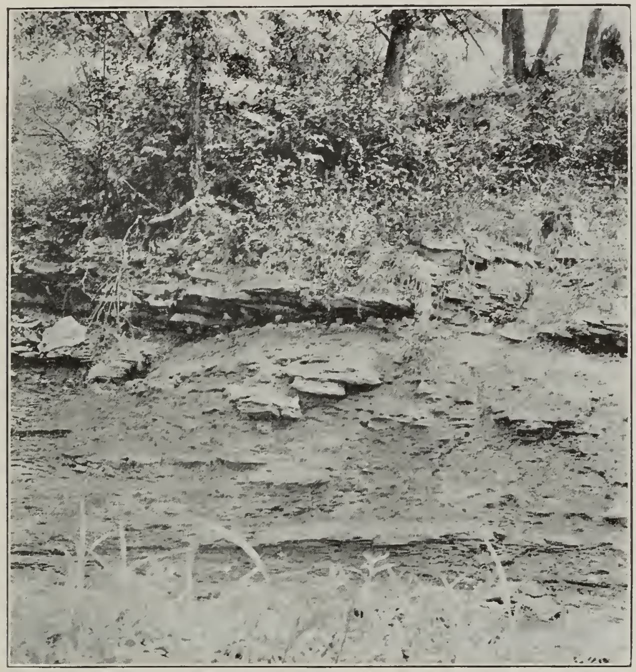


FIG. 19.—Sweetland Creek shale, along Sweetland Creek in the northwest quarter of the Edgington quadrangle.

Devonian (Sweetland Creek) shale which is known to be present at this horizon in many places farther east and south in Illinois.

Mississippian System

Strata of Mississippian age appear to be entirely absent from this immediate region, although chert masses are in places found in the basal conglomerate of the Pottsville that contain casts of Mississippian fossils which indicate that the lower Mississippian strata had originally been deposited over the entire quadrangles and possibly much farther north, but they were removed by erosion prior to the deposition of the Pottsville sediments.

Pennsylvanian System

The Pennsylvanian system is represented in the Edgington and Milan quadrangles by rocks of Pottsville and McLeansboro age and some Carbondale strata are also thought to be present.

The strata of Pennsylvanian age in the Milan and Edgington quadrangles are known from numerous outcrops, and also by means of test borings. Their character is shown in the generalized columnar section in figure 15, and on the following pages by means of sections and descriptions of outcrops.

The greatest known thickness of the Pennsylvanian rocks in the Milan and Edgington quadrangles is in the SW. cor. SW. 1/4 SE. 1/4 sec. 27, Buffalo Prairie Township, where a depth of 231 feet of these rocks was reported in a test boring. In the south part of the Milan quadrangle, where the greatest thickness might be expected on account of the southeastward dip of the Pennsylvanian rocks and the southward inclination of the upper surface of the Devonian, the thickness of the Pennsylvanian rocks is not known to exceed 150 feet.

Fig. 29.—Contact of the Devonian limestone and the basal Pottsville conglomerate, near Andalusia, Illinois.

In the north third of the Milan quadrangle the thickness of the Pennsylvanian rocks ranges from a few feet, where present at all, to about 100 feet, probably averaging about 50 feet. In the middle third of this quad-

rangle the average thickness is probably near 100 feet, and in the south third, the average thickness is perhaps 150 feet. In the west half of the Milan quadrangle the average thickness of the Pennsylvanian rocks is prob-

FIG. 21.—Old caverns in the Devonian limestone, the Pottsville filling of which has been removed by the river.

ably 50 feet greater than in the east half. In the Edgington quadrangle the average thickness of these strata in twenty-one measured records is 170½ feet.

DESCRIPTION OF OUTCROPS

POTTSVILLE FORMATION

The Pottsville formation includes all of the rocks from the base of the Pennsylvanian system up to the base of the Murphysboro or No. 2 coal bed, and is thought to about correspond in age to the Pottsville (lowest Pennsylvanian) formation of the Appalachian region. Stratigraphically it is the lowest Pennsylvanian formation in the quadrangles, over the whole of which it probably underlies the surficial deposits except in limited areas near the larger streams in the north and east parts where in places it has been removed by erosion, leaving the Devonian limestone immediately beneath the Pleistocene materials.

In the Milan and Edgington quadrangles the Pottsville formation consists of variable and mostly discontinuous beds of sandstone, shale, conglomerate, coal, and thin limestone which were deposited on the shoreward part of an advancing sea, producing an overlapping succession of more or less lenticular strata. The advance of this sea was probably interrupted at different times so that minor unconformities which are difficult to distinguish in this region probably occur at different levels. On account of this

variable and lenticular character of the strata it has not been possible to identify any easily recognized stratigraphic units in the Pottsville which persist over all of the quadrangles.

The basal layers of the Pottsville formation in some places consist of conglomerate (fig. 20), in others of shale (fig. 22), and in still others of

FIG. 22.—Unconformable contact of the Devonian limestone and Pottsville shale, near the south line of the NW. ¼ sec. 13, T. 17 N., R. 2 W. A 4-inch layer of limonite follows the upper eroded surface of the Devonian. The two light hummocks are elevations of the Devonian, covered by the limonite layer. Photograph by David White.

sandstone (fig. 23). The contact of the Devonian and Pottsville sediments is well exposed near the top of the face of an abandoned stone quarry in the city of Rock Island, about 200 feet south of Fifth Avenue, west of Thirty-fifth Street. The upper part of the Devonian at this place consists of yellowish-brown, rather thin-bedded limestone, having the upper surface strongly iron-stained. This limestone is overlain by a thickness of a few feet of brown or red, sandy conglomerate composed of coarse sand, and pebbles mostly 1 to 2 inches in diameter, with a few boulders ranging up to 12 inches. All of the pebbles and boulders are of flint or chert. At this place the conglomerate extends down into, and fills, a small cavern in the underlying Devonian limestone. Some of the chert boulders in the conglomerate contain imperfect casts of fossils among which the following have been identified by Ulrich:

Fossils from chert boulders in the basal Pottsville conglomerate.[1]

Orthothetes, near an unnamed Waverly and Keokuk species.

Spirifer keokuk or *S. leidyi;* cast of pedicle valve.

Productus sp., may be either *P. levicostatus* White from the Burlington limestone, or *P. tenuicostatus* Hall, from the St. Louis limestone.

Bellerophon-like shell, undeterminate cast.

Rhombopora sp., resembling *R. dichotoma* Ulrich.

The fossils listed above indicate that the cherts from which they came are of Mississippian age. Some Niagaran cherts are also present in this conglomerate.

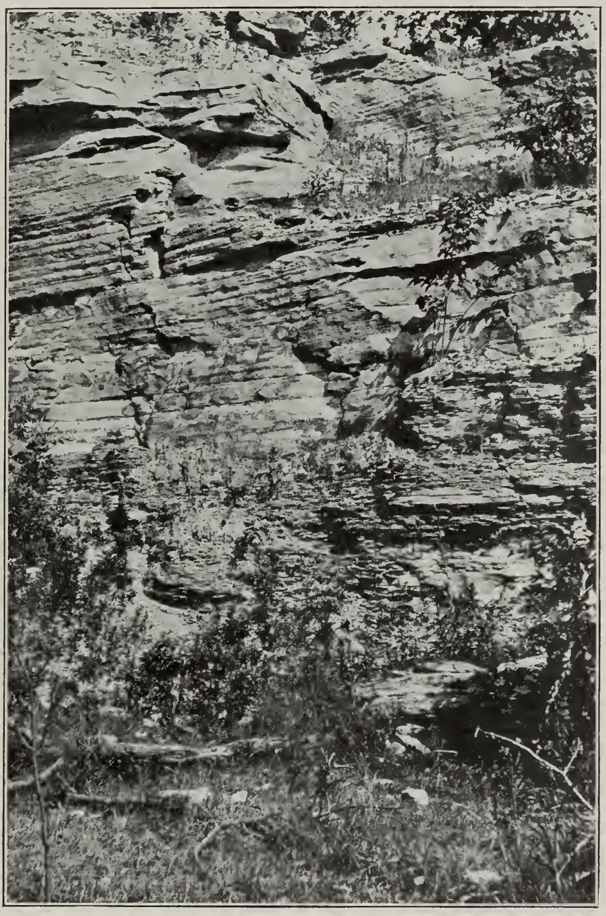


FIG. 23.—Thin-bedded sandstone in the lower part of the Pottsville, formerly quarried in sec. 7, Drury Township.

The greatest development of conglomerate noted in the basal part of the Pottsville was in the west bank of Mill Creek, about one-fourth mile

[1]An additional list of fossils from this conglomerate, determined by Ulrich: *Fenestella binodata* Condra. *Fenestella gracilis* Condra. *Fistulipora carbonaria* Ulrich, *Polypora bassleri* Condra. *Meekopora prosseri* Ulrich, *Stenopora heteropora* Condra.

southwest of the center of sec. 31, T. 17 N., R. 1 W. It is here 12 feet thick, and consists of layers of conglomerate, 1 to 1½ feet thick, interbedded with layers of sandstone. The pebbles range in size up to 4 inches in diameter and are all siliceous, ninety-eight per cent of them being chert and the remainder white quartz. Casts of a few brachiopod shells, indicating Mississippian age, were also noted in these pebbles. A similar conglomerate outcrops in a ravine a short distance northeast of Doxie School, in sec. 30, T. 17 N., R. 1 W. Another exposure of conglomerate occurs in the south bank of a creek, about 200 yards west of the center of sec. 13, T. 17 N., R. 2 W., where the deposit consists mostly of pebbles 2 to 3 inches in diameter, with some larger boulders up to 8 inches, cemented together with yellow calcite.

In some places the Devonian limestone is immediately overlain by Pottsville sandstone, with no intervening conglomerate. Such an outcrop occurs near the mouth of Coal Creek, in the SE. ¼ sec. 29, T. 17 N., R. 3 W., which furnished the following section.

Section of strata exposed along Coal Creek in sec. 29, T. 17 N., R. 3 W.

	Thickness *Feet*
Pennsylvanian (Pottsville) sandstone:	
Sandstone, yellowish gray, micaceous, thin bedded	9
Sandstone, in irregular layers, somewhat shaly in lower part	4
Shale, gray and brown, sandy, in discontinuous layers of variable thickness	½–2
Devonian limestone:	
Dolomite, yellowish brown, in layers ½ to 1 foot thick, containing the fossils *Stropheodonta demissa, Spirifer iowensis, S. subvaricosa,* and *Atrypa reticularis*	3+

The altitude of the top of the Devonian limestone at this place is about 563 feet. This is 7 feet lower than the top of the Devonian at the west end of the wagon bridge, 16 rods farther down this creek, and 9 feet lower than the top of the Devonian limestone in the east bank of the creek opposite the exposure at the bridge. About 20 rods up the creek from the place where the above section was made, a thickness of 8½ feet of somewhat cherty Devonian limestone outcrops to an altitude of about 566 feet above sea level. Farther west an outcrop of Devonian limestone in the Edgington quadrangle occurs in the SE. ¼ sec. 17, Montpelier Township, on the Iowa side of the river, where the elevation of its surface reaches 588 feet, and again in the SW. ¼ sec. 27, T. 17 N., R. 3 W., where the altitude is about 580 feet. In the town of Cable, in the southeast part of the Milan quadrangle, the elevation of the top of the Devonian is 549 feet.

The basal Pottsville sandstone and shale in many places fill cavernous depressions and passages that extend for a considerable distance into the Devonian limestone (see fig. 21). The sandstone is mostly white, soft, and

moderately coarse grained; the grains are usually angular as a result of secondary crystalline enlargement. In some places the sand contains carbonaceous material in the form of wood fragments. The sand is in some localities interlaminated with shale which may be green and unctuous, or black from carbonaceous material. Pottsville deposits occurring in a cavern in the Devonian limestone in an old quarry north of Fifth Avenue, near Twenty-eighth Street, in Rock Island, showed rill marks of the kind once described as fossil fern leaves, and called *Dendrophycus*. In the south bank of Mississippi River between Forty-second and Forty-fourth streets in Rock Island, the Pottsville sandstone is exposed in contact with the Devonian limestone, and at one place its lowermost layer contains brachiopods that had weathered out of the Devonian limestone, and later become imbedded in the basal layer of the overlying Pottsville formation. In the old quarry near Thirty-fifth Street and Fifth Avenue, in Rock Island, a cavern in the Devonian more than 20 feet deep, and equally wide, is filled with Pottsville shale that contains impressions of *Calamites,* and leaves of ferns. The wall of the cavern is lined with a layer of impure limonite, from one inch to several inches thick, in the form of gossan. Such a limonite deposit is common at the contact of the Devonian-Pennsylvanian unconformity in all of this region. On Mill Creek in sec. 31, T. 17 N., R. 1 W., it is almost everywhere present at this contact, its thickness varying from 6 inches to 2 feet. It is also exposed in the bottom of a creek near the south line of the NW. ¼ sec. 13, T. 17 N., R. 2 W., where it covers small, dome-like elevations of the Devonian rock surface (fig. 22).

In one place in a mine in the northeast corner of sec. 20, T. 77 N., R. 2 E., coal rests directly on the Devonian limestone, and in other parts of the same mine a thin underclay separated the coal and limestone. Similar conditions are known in a coal mine near the center of sec. 16, of the same township, as shown in the following section:

Section of shaft of coal mine near the center of sec. 16, T. 77 N., R. 2 E.

	Thickness Ft.	In.
Clay, yellow	5	..
Shale, soft, light gray	5	..
Sandstone	14	..
Shale ("miner's slate"), with septaria	1	..
Coal	2	8
Underclay	12	..
Shale, light gray, and "miner's slate"	17	..
Coal	2	..
Shale, light gray, and "miner's slate"	50	..
Coal	4	..
Underclay	2	..
Limestone (Devonian)	+	..

In the shale pit formerly worked by the National Coal Company, near Sears, a coal bed is separated by only a few feet of shale from the Devonian limestone, as shown in the section given below:

Section of abandoned clay pit of the National Clay Company, in the bluff of Rock River, near Sears.

	Thickness *Feet*
Loess	40
Sandstone, white, friable, with impressions of *Calamites* and *Stigmaria*	8
Shale, dark, containing disintegrated septaria, and other concretions	2
Shale, gray, and dark gray	6
Coal, weathered	1
Underclay, unctuous, in places red or variegated, and known in the clay works as "castile clay"	3
Shale, dark gray, with some concretionary material in the upper part	8
Coal	2
Underclay, white, sandy	4
Shale, greenish-gray	1
Limestone (Devonian)	..

In the north bank of Rock River, at Black Hawk's Watchtower the succession of strata described below is exposed in the lower part of the bluff:

Section of strata exposed at Black Hawk's Watchtower, east of Sears.

	Thickness *Feet*
Loess	50
Till, leached, not well exposed	3
Sandstone, coarse	10
Sandstone, dark, soft, shaly	2
Shale, dark	1
Coal	1
Shale, dark, and underclay, with streaks of sandstone and coal, not well exposed	46
Limestone (Devonian)	4+

About three miles east of Andalusia there is exposed near the base of the Mississippi bluffs a thickness of 20 or more feet of sandstone, in layers 1 to 1½ feet thick, which doubtless lies near the base of the Pottsville formation.

The sections given above, and the records of several of the coal-test borings in the quadrangles, show that two thin coal beds are generally present and in many places three or more coals occur in the Pennsylvanian rocks of this region. One of these coals lies 30 to 50 feet below the horizon of the Herrin (No. 6) coal, and another one occurs 50 to 90 feet higher than this lower coal. These are usually thin, but in a few places, as along Coal Creek west of Andalusia, in the country near Buffalo, and along a creek near the west side of sec. 13, T. 17 N., R. 2 W., they have been profitably

mined by drifts for local use. At the last-named locality the coal dips from both sides at the rate of 15 feet in a distance of 100 feet, toward a trough or syncline which extends in a general northwest-southeast direction. West of Andalusia, along Coal Creek, and in the banks of the streams that join the Mississippi on the south, between Coal Creek and Illinois City, some part of the following section of lower Pennsylvanian strata is exposed above the basal sandstone of the Pottsville formation:

General section of the Pennsylvanian rocks, exposed along Coal Creek and other streams south of Mississippi River, between Andalusia and Illinois City.

	Thickness
McLeansboro formation—	*Feet*
15. Sandstone, thin bedded, gray to yellow, micaceous	12
14. Shale, gray, sandy, in layers 1 to 6 inches thick, with bands of sandstone and thin clay-ironstone concretions	25
13. Coal (locally present)	½
12. Shale, gray	4
11. Limestone, concretionary, argillaceous (locally absent)	1– 4
Carbondale formation—	
10. Coal, Herrin (No. 6) bed (?); locally present	4–11
Pottsville formation—	
9. Sandstone, thin bedded	4½
8. Coal (locally present)	1– 1½
7. Shale, gray to dark, with many small concretions of clay-ironstone	13
6. Coal (locally present)	½–1½
5. Sandstone, gray, micaceous, in thin layers, with a thicker layer at the top	3½
4. Shale, gray to black, the middle part with large concretions and bands of dark nodular limestone the surfaces of which are covered with "cone-in-cone" structures, and in places nodules covered with pisolite	21
3. Sandstone, hard, quartzitic, in two layers	1½
2. Coal, in some places	½–2
1. Shale, gray to dark	23

In the banks of a stream in the NE. ¼ sec. 36, T. 17 N., R. 4 W., the limestone member, number 11 in the foregoing section, is 3½ feet thick, and contained the fossils *Girtyina ventricosa, Productus cora, Productus semireticulatus, Spirifer cameratus,* and *Composita argentea.* At this place a bed of coal 2½ feet thick underlies the limestone, being separated from it by 6 inches of shale. This is probably the Herrin (No. 6) coal bed with the typical limestone cap rock that is usually present in other parts of the quadrangles and farther east, in Fulton County.[1]

In a tributary that joins this creek from the east about 50 rods east of the exposure last mentioned, and in the banks of a stream still farther east, this limestone is 4½ feet thick, and furnished *Girtyina ventricosa, Productus cora, Productus semireticulatus, Spirifer cameratus, Spirifer cameratus* var. and *Composita argentea.* At the former place the underlying coal is only about 6 inches thick, and is separated from the limestone by 3 feet of

[1]Mr. Harold E. Culver of the State Geological Survey has recently shown the presence of the *Girtyina* limestone in this region.

shale. The upper layer of limestone at this place contains many calcite-filled tubes which average nearly one-fourth inch in diameter. These are among the few exposures in which the Herrin Coal and the overlying limestone containing *Girtyina ventricosa* can be certainly recognized, and its stratigraphic relations determined in the northern part of the quadrangles. At this place it lies about 35 feet above the horizon of large concretions with cone-in-cone and pisolite structures, and about 75 to 85 feet above the base of the Pottsville formation, at an altitude of about 660 feet above sea level.

Strata equivalent to members 1 to 14, inclusive, of the foregoing section outcrop along a creek a short distance west of the middle of the south half of sec. 30, T. 17 N., R. 3 W., and along the creeks that join the river near the middle of the S. ½ sec. 25, T. 17 N., R. 4 W. Members 1 to 11, inclusive, can be recognized along a creek that follows near the west side of the S. ½ sec. 30, T. 17 N., R. 3 W., but the limestone is only about one foot thick, and the Herrin coal is not present in these outcrops. Members 4 and 5 of this section can be seen in outcrops along the lower course of the creek that joins the river in the NW. ¼ sec. 32, T. 17 N., R. 4 W., and strata belonging to higher levels are exposed farther up this stream. In the SW. ¼ sec. 4, T. 16 N., R. 4 W., a coal bed 20 to 26 inches thick has been worked by drift in a number of places at an altitude of 710 to 714 feet above sea level. The dip of the coal at these localities is variable, the strongest slope being toward the south, at the rate of about one foot in 10 feet. A slight western inclination was also present. The coal is overlain by a thin-bedded sandstone or sandy shale 3 or 4 feet thick. The dark shale bed containing concretionary limestone masses covered with cone-in-cone structure and pisolite is also exposed about a quarter of a mile above the mouth of the creek that joins the river in the NW. ¼ sec. 33, T. 17 N., R. 4 W. About 40 rods farther up this creek a coal bed, 22 inches thick, overlying a thin-bedded, micaceous sandstone has been worked in a small way at an altitude of about 582 feet. The strata in this part of the quadrangle are more or less undulating, dipping in different directions in different places, but the conspicuous prevailing dip in this part of the area is southward, with a smaller inclination toward the west. The zone of large concretions with cone-in-cone structure and pisolite is conspicuous in all of the streams where its horizon is exposed. It occurs at a level about 35 to 50 feet above the base of the Pottsville. The altitude of this "cone-in-cone" and pisolitic zone along Coal Creek is about 623 feet above sea level, but about 5½ miles farther west, in the NW. ¼ sec. 33, T. 17 N., R. 4 W., the elevation of this "cone-in-cone" concretionary horizon has declined to about 576 feet above the sea. Still farther west sandstone becomes more prominent in the Pennsylvanian section. Along a creek that crosses the middle part of sec. 1, T. 16 N., R. 5 W., the following succession of strata is exposed:

Section of rocks exposed along a stream in sec. 1, T. 16 N., R. 5 W.

	Thickness *Feet*
7. Shale, gray to blue	28
6. Shale, white (pottery clay)	5-7
5. Shale, dark and gray	36
4. Shale, with ironstone and nodular bands 1 to 3 inches thick, with "cone-in-cone"	2½
3. Shale, dark	22
2. Shale, dark and gray	10
1. Sandstone	22

The white shale member number 6 in the foregoing section outcrops near the middle of the south half of the section. It was worked by Mr. Tyler prior to 1890 for white pottery clay which was used at that time in the manufacture of jugs, crocks, and jars at four pottery plants in and near Illinois City. Considerable clay was also hauled to Fairport, Iowa, where it was manufactured into similar wares. A similar clay that burns white occurs on land of A. J. Lyon, half a mile north of Illinois City, and probably represents the same bed as that formerly worked by Mr. Tyler. At this place the white shale bed lies about 35 feet above the zone of small dark concretions, the base of it being about 695 feet above sea level. It belongs to a level several feet above the level of the Rock Island (No. 1) coal bed which is usually absent along these streams south of the Mississippi, but possibly outcrops in the river's north bank, 3½ miles northeast of this place at an altitude of about 658 feet, about 60 feet above the top of the Devonian limestone exposed in the bank of Pine Creek one mile farther northeast.

The sandstone bed in the lower part of the Pottsville formation continues to thicken farther westward, as shown by the exposures along a stream in the NE. ¼ sec. 2, T. 16 N., R. 5 W., where the following section was made:

Section of strata exposed in the NE. ¼ sec. 2, T. 16 N., R. 5 W.

	Thickness *Feet*
Coal (alt. about 674)	1½+
Shale, black, with large concretions, laminated in lower part	22
Shale, gray to dark	6
Shale, light and dark, partly concealed	20
Sandstone, gray to yellow, micaceous, in thick and thin layers, some of which are cross-bedded	35

The strata at this place dip south and a little west at the rate of about one foot in a distance of 10 feet. The coal has been worked by drifts in two or three places in this vicinity for local use.

About one mile west of the place where the last section was made the following succession of strata outcrop in the banks of a stream in the east half of sec. 3, T. 16 N., R. 5 W.:

Section of strata exposed in the E. ½ sec. 3, T. 16 N., R. 5 W.

	Thickness Feet
Coal (altitude about 656)	2
Shale, gray and dark	18
Coal, locally present	1
Limestone, concretionary, with iron	¼
Cone-in-cone band	⅓
Shale, dark, with large concretions covered with cone-in-cone structure	11
Shale, dark alternating with clay-ironstone bands in layers 1 to 4 inches thick	2
Shale, gray, sandy	6
Sandstone (partly concealed), with an iron-cemented conglomerate 1 foot or more thick at the base	45
Shale, gray and dark	25
Coal (altitude about 563 feet)	1⅔
Sandstone, in thin layers	7
Shale, black	3

In the foregoing section the coal at the top is equivalent to the upper member of the preceding section, the westward dip being about 11 feet to the mile. This coal outcrops near the middle of section 2 at an altitude of about 665 feet. The sandstone bed, number 5 of the last section, clearly corresponds with the lowest member in the preceding section.

The succession of strata exposed along a stream in the W. ½ of section 3 of this township is as follows:

Section of strata exposed in the W. ½ sec. 3, T. 16 N., R. 5 W.

	Thickness Feet
Sandstone	15
Shale, gray, sandy	21
Coal	1½+
Sandstone	4½
Shale, dark	10
Shale, light	6
Shale, dark	9½
Sandstone	7
Shale, sandy	10
Sandstone, partly concealed	30+

For a distance of one and one-half miles west from the place where the last section was made, as far as Jimtown School, a massive sandstone outcrops in the south bank of the river to a height of more than 100 feet above the level of the flood plain. The foot of the bluff is concealed by talus, so that the full thickness of the sandstone could not be seen, but it can not be less than 60 feet and probably in places reaches 80 feet. This is doubtless the continuation of the sandstone exposed in picturesque ledges along Pine Creek in secs. 17 and 18, T. 77 N., R. 1 E. This sandstone rests with marked unconformity upon different levels of older Pennsylvanian

strata in this region; and possibly it is to be correlated with the massive sandstone that unconformably overlies different levels of McLeansboro strata in Clark and Coles counties.

In the banks of the creek that joins the river just east of Jimtown School, the following succession of strata is exposed.

Section of rocks exposed in secs. 4 and 5, T. 16 N., R. 5 W.

	Thickness *Feet*
Sandstone	50 to 70
Shale, dark	30
Shale, dark and light	11
Sandstone	12
Coal (altitude 558 feet)	1½
Underclay, gray	2

The coal has been drifted on in several places below the school house in this vicinity. The strata rise toward the west at the rate of about one foot in a distance of 60 feet. The thick sandstone at the top of the section probably fills an old channel, and rests in erosional unconformity on the underlying strata. The altitude of the base of the thick sandstone near the Jimtown School is about 611 feet above sea level, while that of the base of this sandstone two miles farther east is about 571 feet above the sea. Across the river from Jimtown School, near the mouth of Sweetland Creek, Devonian limestone is exposed to a height of about 572 feet above the sea.

Along a creek that crosses the south half of sec. 5, of this township, a one-foot conglomerate lies above 17 feet of shale, at the base of the thick sandstone bed at an elevation of about 619 feet. At this place the sandstone is underlain by 17 feet or more of dark shale.

Along the Muscatine-Rock Island wagon road up the hill in the east bank of the river, near the middle of the south side of sec. 6, T. 16 N., R. 5 W., there is exposed the following succession of shale which dips gently toward the east.

Strata exposed along wagon road near middle of south side of sec. 6, T. 16 N., R. 5 W.

	Thickness *Feet*
Sandstone, in thick and thin beds, in places massive and strongly cross-bedded, the false bedding planes dipping toward the west. This is probably the thick sandstone exposed near the top of the bluff west of Jimtown School	38
Shale, dark	12
Clay-ironstone band	⅓
Shale, dark	9
Clay ironstone bands alternating with bands of shale, 1 to 3 inches thick	2½
Shale, dark	16
Shale, gray, sandy	12
Sandstone	6

About 40 rods east of this road a quarry was formerly worked in a sandstone bed that corresponds with the basal member of the foregoing section (fig. 23). The sandstone is 22 feet thick in this old quarry. It is underlain by 2½ feet of black shale, and is followed above by a thickness of 11 feet of gray, sandy shale. The wagon road up the hill half a mile east of the road, where the last section was made, passes over a thickness of 55 feet of light and dark shale which corresponds to that portion of the foregoing section between the upper and basal sandstones. The following succession of strata, exposed along Copperas Creek, corresponds in a general way with those outcropping along the streams south of Mississippi River, described above. The youngest rocks appear near the headwaters of this creek where the section given below is exposed near the middle of the east side of sec. 36, T. 16 N., R. 4 W.:

Section of rocks exposed in sec. 36, T. 16 N., R. 4 W.

	Thickness *Feet*
Shale, gray	7
Shale, red and pink	9
Shale, gray	6
Sandstone, thin bedded	12

The elevation of the top of the exposure at this place is about 740 feet. About half a mile farther up this creek a sandstone 5 feet thick, dipping toward the south, is exposed above the level of the uppermost shale in the above section. Strata belonging below the basal member of the foregoing section outcrop in the east bank of a tributary of Copperas Creek, along the wagon road near the middle of the W. ½ sec. 27, Buffalo Prairie Township, as shown in the section given below:

Section of strata near the middle of W. ½ sec. 27, T. 16 N., R. 4 W.

	Thickness *Feet*
Shale, gray	4½
Coal (altitude about 710 feet)	1⅙
Shale, sandy, gray	13
Sandstone	9

Rock Island (?) coal and associated strata.—From one-half mile to one mile farther down the creek in the SE. ¼ sec. 21, and the SW. ¼ sec. 22, T. 16 N., R. 4 W., the following succession of strata outcrop at an altitude lower than the base of the last section:

Section of strata exposed in the SE. ¼ sec. 21, T. 16 N., R. 4 W.

	Thickness *Feet*
Shale, dark	11
Shale, dark and light, with concretionary clay-ironstone bands	16
Limestone, dark, fossiliferous	1½+
Coal (No. 1) (?) (altitude about 654 feet)	1½

The coal has been worked by drifts in a number of places near the junction of this stream with Copperas Creek. Rocks corresponding to some part of the shale portion of the last section are exposed in the banks of Copperas Creek in places for a distance of two miles above the mouth of this stream. About three miles farther west, along a tributary of Copperas Creek, in the W. ½ sec. 19 and the N. ½ sec. 24, of the same township, and farther west in the Edgington quadrangle, the Rock Island (No. 1) (?) coal and its limestone cap rock are absent, and their place appears to be occupied by a sandstone bed 28 feet thick, which is thought to correspond to the sandstone that outcrops in the upper part of the river bluff west of Jimtown School.

Fig. 24.—Sandstone overlying a thin coal bed in the lower part of the Pottsville formation, in the SW. ¼ sec. 23, Drury Township.

In the SW. ¼ sec. 23, T. 16 N., R. 5 W., there is exposed the following succession of strata (see fig. 24) belonging to a level below the sandstone above described:

Section of strata outcropping in sec. 23, T. 16 N., R. 5 W.

	Thickness *Feet*
Sandstone, yellowish gray	6
Coal	½ to 1
Shale, gray and dark	18

The lowest strata appearing along Copperas Creek are exposed along a stream in the NW. ¼ sec. 29 of Drury Township.

Section of strata in the NW. ¼ sec. 29, T. 16 N., R. 5 W.

	Thickness Feet
Shale, gray	7
Shale, sandy, or shaly sandstone	11
Coal (altitude 592 feet)	1
Underclay, gray	½ to 1
Sandstone, thin bedded	19

In places these strata lie nearly horizontal, and in others they dip southward at a low angle.

A limestone that may represent the limestone above the Rock Island (No. 1) (?) coal bed is reported in the log of a boring in the NE. ¼ NW. ¼ sec. 34, T. 16 N., R. 4 W., at an altitude about 642 feet above sea level. This coal and the dark limestone cap rock are exposed in the SE. ¼ sec. 21, about one and one-half miles north of the test boring last mentioned, but they are not known farther west in the Edgington quadrangle on the Illinois side of the river. The coal outcrops on the Iowa side of the river in the north part of the Milan quadrangle, where it has been mined in a small way a short distance north of the center of sec. 11, T. 17 N., R. 2 E., at an elevation of about 650 feet, and near the northwest corner of sec. 15 of the same township, where the elevation is about 660 feet. It also outcrops near the middle of the SE. ¼ sec. 20, T. 77 N., R. 1 E., at an elevation of about 658 feet. Most of the logs of coal-test borings in secs. 16, 21, 22, 27, 28, 29, and 34, T. 16 N., R. 4 W., report neither the coal nor the dark limestone cap rock that usually overlies it. These strata are not exposed at any other places along the streams in the northern, middle, and western parts of these quadrangles.

CARBONDALE AND MCLEANSBORO FORMATIONS

Along Camp Creek and its branches, in the southeast quarter of the Edgington quadrangle, the Herrin (No. 6) coal bed, with its dark limestone cap rock containing *Girtyina ventricosa,* outcrops in several places at altitudes ranging from 645 to 675 feet. Along the roadside in the north bank of Camp Creek, near the middle of the S. ½ sec. 24, T. 15 N., R. 4 W., the following succession of rocks is exposed:

Section of rocks exposed near the middle of the S. ½ sec. 24, T. 15 N., R. 4 W.

	Thickness Feet
Sandstone, thin bedded	5
Limestone, dark, shaly, containing *Girtyina ventricosa*	12
Coal (Herrin or No. 6, altitude 672 feet)	2½
Underclay, gray	4

The sandstone member number 4 of the above section is said to be 35 feet thick in an old coal shaft near this place.

A few rods south of the exposure above described, the Herrin coal outcrops at about the same elevation, and is overlain by sandstone, the limestone cap rock being absent. Here, as elsewhere, such alternations of sandstone and limestone immediately above the coal bed within so short a distance are thought to indicate erosional unconformity, the limestone normally lying above this coal having been removed by erosion previous to the deposition of the sandstone that in places rests directly upon this coal bed. Probably in places the coal also was entirely removed. Herrin (No. 6) coal was formerly worked by several drifts near the south side of the NW. ¼ sec. 19, T. 15 N., R. 3 W., at an altitude about 675 feet above sea level. No good exposures were seen in the last locality, but fragments of dark limestone on the old coal dumps indicate that the dark limestone cap rock that normally overlies this coal in the vicinity of Matherville and in Fulton County, is also here present above the coal. This same coal bed is exposed in two or three places in the NE. ¼ SE. ¼ sec. 24, T. 15 N., R. 3 W., where the following section was made, but the dark limestone that usually overlies it is absent.

Section of strata exposed in the NE. ¼ SE. ¼ sec. 24, T. 15 N., R. 3 W.

	Thickness *Feet*
Shale and sandstone	17
Sandstone, thin bedded	8
Coal (No. 6, altitude 673 feet)	2
Shale, gray above and dark below	9

Strata similar to those in the outcrop above described are exposed near the middle of the north side of sec. 25 of Duncan Township, where the altitude of the coal is about 662 feet. The Herrin (No. 6) coal also has been drifted on in several places in the SE. ¼ sec. 23 of Duncan Township, at an elevation of about 657 feet above sea level. A section of the rocks in this locality is given below:

Section of strata exposed in the SE. ¼ sec. 23, T. 15 N., R. 4 W.

	Thickness *Feet*
Sandstone, or sandy shale	16
Coal (No. 6, altitude about 657 feet)	2
Shale, light and dark	20

In the south bank of Little Camp Creek, in the SW. ¼ sec. 34, Duncan Township, the Herrin coal and associated strata are exposed, as shown in the section given below:

Section of rocks exposed in the SW. ¼ sec. 34, T. 15 N., R. 4 W.

	Thickness *Feet*
Coal (No. 6, altitude 658 feet)	2
Shale, gray and dark	23
Coal	½
Shale	2

The Herrin coal and the dark limestone cap rock outcrop near the middle of the north side of the SE. ¼ sec. 27 of the same township, as shown below:

Section of rocks exposed in north side of the SE. ¼ sec. 27, T. 15 N., R. 4 W.

	Thickness *Feet*
Sandstone	3
Limestone, dark with several fossils	2
Coal (Herrin or No. 6)	3
Shale, light and dark	12

The limestone above the Herrin coal at this place furnished the fossils *Girtyina ventricosa, Orbiculoidea missouriensis, Productus cora, Productus semireticulatus, Marginifera muricata, Spirifer cameratus,* and *Composita argentea,* which species also occur in the limestone above this coal farther southeast in Fulton County.

Farther west, in the southwest quarter of the Edgington quadrangle, no rocks of Pennsylvanian age outcrop along Eliza Creek or its tributaries or on Winters Creek, or along the tributaries of Mississippi River south of Copperas Creek, except a few small exposures in sec. 6, Eliza Township, where the following succession of strata was seen in the bank of the river nearly a mile west of the quadrangle:

Strata exposed in the bank of the river near the west side of sec. 6, T. 15 N., R. 5 W.

	Thickness *Feet*
Coal (altitude about 573 feet)	1½
Shale	3
Sandstone	14 to 17

In the southeast quarter of the Milan quadrangle the Herrin (No. 6) coal is exposed in several places in the vicinity of Matherville, at elevations ranging from 624 to 650 feet above sea level. The coal bed varies considerably in thickness from place to place; even in the same mine it is said to be 4 feet thick or more in some places, and to pinch out entirely in others. The thickness is said to be more persistent in a north-south than in an east-west direction. The dark limestone is usually present above the coal in this region.

Along a stream near the center of sec. 33, Preemption Township, the Herrin coal has been mined in a drift at an altitude of 652 feet. The bed at this place is 3 feet 10 inches thick, and is overlain by a thickness of

12 feet of dark limestone called "blue rock" by the miner. A section of the strata exposed at this locality is as follows:

Section of rocks exposed near the middle of sec. 33, T. 15 N., R. 2 W.

	Thickness *Feet*
Sandstone, white, shaly	3
Shale, dark and gray	11
Limestone, dark, shaly, fossiliferous	9
Coal (No. 6, altitude about 652 feet)	2½
Shale, gray	7
Sandstone	1
Shale, gray	1½

The fossils in the limestone above the coal at this place include *Girtyina ventricosa, Productus cora, Spirifer cameratus, Composita argentea.*

In the shaft of mine No. 3 of the Coal Valley Mining Company, in the SE. ¼ sec. 27, Preemption Township, the Herrin (No. 6) coal lies about 69 feet below the surface at an altitude of about 624 feet above the sea. The coal in this mine is pockety, ranging in thickness from less than 3 to nearly 5 feet and dipping in different directions in different parts of the mine.

About 30 rods north of the place where the last section was made, a thickness of 12 feet of sandstone is exposed at the level of the limestone member in the detailed section last described. Along the wagon road up the hill on the east side of this creek, along the north side of the NE. ¼ sec. 33, Preemption Township, the following succession of strata is exposed:

Section of strata exposed along the north side, sec. 33, T. 15 N., R. 2 W.

	Thickness *Feet*
Shale	3
Limestone, concretionary, with cone-in-cone structure	1 to 2
Shale, gray	7
Sandstone	16

The altitude of the concretionary limestone is about 693 feet, or about 41 feet higher than the level of No. 6 coal less than a mile farther south.

In a drift mine operated by Dougherty Brothers in the SW. ¼ sec. 26, Preemption Township, the Herrin coal is worked at an altitude of about 646 feet. The bed is 3 to 4 feet thick, and is overlain by 2 feet of black, fissile shale, followed above by 14 feet of dark limestone underlying 13 feet of sandstone.

A coal-test boring in the town of Cable penetrated the following succession of Pennsylvanian rocks, as shown in the log furnished by Mr. B. B. Peterson:

Log of test boring in the town of Cable

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system—		
Pleistocene and Recent—		
Soil and clay	9	9
Pennsylvanian system—		
Pottsville formation—		
Sandstone and shale	3	12
Limestone, blue, shaly	9	21
Coal (No. 1 (?) altitude 654 feet)	3½	24½
Underclay and shale	57	81½
Sandstone	30	111½
Coal (altitude 585 feet)	2½	114
Underclay and shale	12	126
Devonian system—		
Limestone	52	178

The altitude of the upper coal, possibly No. 1, at this place is about 654 feet, and the elevation of the top of the Devonian limestone is about 549 feet.

This coal is also exposed along a stream south of the wagon road in the N. ½ sec. 20, Richland Grove Township, where the following section was made:

Section of strata exposed along a stream in sec. 20, T. 15 N., R. 1 W.

	Thickness *Feet*
Limestone, dark	2+
Coal (No. 1(?), altitude about 667 feet)	2
Underclay	4

In an abandoned drift mine in the NE. ¼ sec. 20, T. 15 N., R. 1 W., this same coal bed lies at an altitude of 662 feet, and ranges in thickness from 2 to 3 feet. In a local mine working this coal about one-half mile east of Cable, the bed is said to average 3½ feet thick and lies at an elevation of about 646 feet. The operator reported that the coal was thickest in the lowest part of the depressions, and that dark shale comes in above the coal and has the greatest thickness over the lowest part of the depressions.

In mine No. 2 of the Coal Valley Mining Company at Sherrard, it is reported that the coal ranges in thickness from 3 to 5 feet in places where it has been mined, but it becomes so thin toward the east, north, and west that it does not pay to work it farther in those directions. The thickness persists toward the south, in which direction they have mined into the old works at Cable. The coal is said to be undulating, the ridges and troughs corresponding in a general way with the hills and

valleys in the surface. A difference in elevation between the crest of the ridges and the bottom of the troughs is in some places as much as 12 feet. The coal is reported to be usually thicker in the troughs than in the ridges. The altitude of the coal in the shaft of this mine is about 612 feet above sea level.

Over the middle part of the Milan quadrangle the glacial drift is more than 100 feet thick, and no exposures of Pennsylvanian rock are to be seen.

In a test hole put down a few rods south of the middle of the north side of sec. 32, T. 17 N., R. 1 W., blue limestone was reported 40 feet below the surface, at an altitude of 650 feet. This limestone was probably the cap rock or dark limestone that usually overlies the Herrin (No. 6) coal bed. Farther west in the Milan quadrangle, if the Herrin coal bed is present on the south side of Mississippi River, it is thin, and the dark limestone that usually occurs above it in the southeast part of the quadrangles, and possibly north of Mississippi River in this area, is absent, so that the Herrin coal bed can not be distinguished.

A coal 2½ feet thick has been stripped in the bed of a creek near the southeast corner of sec. 33, T. 17 N., R. 3 W. This coal lies at an altitude of about 650 feet, and is overlain by a dark shale bed containing some calcareous nodular material, and may possibly represent the Rock Island bed.

UNCONFORMITIES WITHIN THE PENNSYLVANIAN

An intra-Pennsylvanian unconformity is believed to be indicated in the exposures in the SW. ¼ sec. 24, T. 15 N., R. 4 W., where sandstone immediately overlies the Herrin (No. 6) coal, and only a few feet distant at the same level the normal dark limestone immediately overlies this bed. A large unconformity is also thought to be indicated in Montpelier and Drury townships, where a thick-bedded, coarse-grained sandstone replaces shale and other strata within short distances in a horizontal direction. The Herrin coal and the overlying limestone containing *Girtyina ventricosa* overlap the underlying strata in marked unconformity.

An old channel in the coal bed in the Sherrard mine (fig. 25) is thought to furnish additional evidence of an unconformity within the Pennsylvanian. Operations in this mine, which have extended under nearly two sections of land, have disclosed a channel about 300 feet wide in the coal bed where the coal is either wholly absent, or so thin and affected to such an extent with faults and slips that it could not be profitably worked. The channel follows a sigmoid course from northeast to southwest, as shown in the sketch of the mine map, figure 25. It has been traced from near the center of the south side of sec. 5, T. 15 N., R. 1 W., to near the center of the NE. ¼ sec. 4, of the same township, a distance of

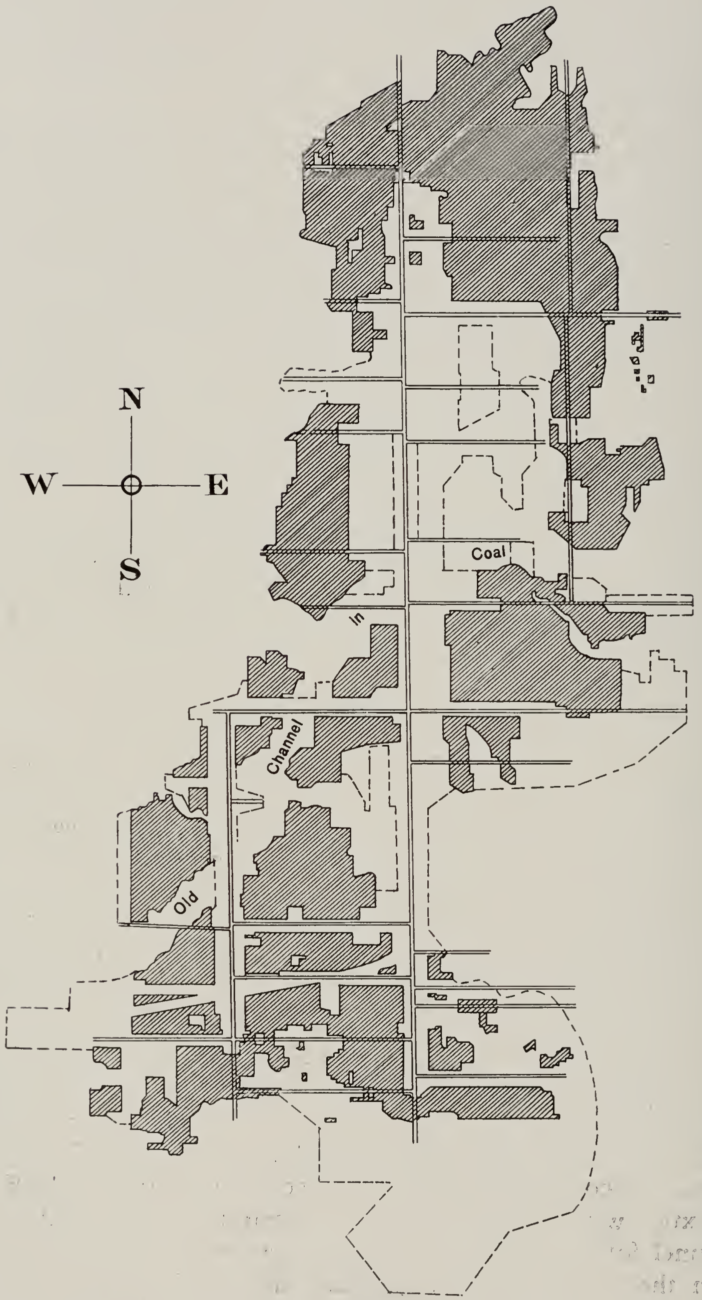


FIG. 25.—Mine map of mine No. 2 of Coal Valley Mining Company at Sherrard, showing location of old channel in the coal.

about one mile. Two smaller unproductive belts, which appear to be tributaries, join the main channel from the northwest.

One possible explanation of these channels is that they represent ancient drainage courses in the original peat swamp in which the coal was formed. However, if these represent such channels, like that of Dismal River in the Great Dismal Swamp, the dark limestone cap rock, which is marine, would be expected to extend across the channel, bending down into it from both sides, if a depression existed there when the limestone was laid down; or owing to later compression of the peat, it might bend upward at the margins, and lie at a higher level above the channel if the latter was filled with mud or sandy sediment before the limestone was deposited.

Instead of either of these conditions prevailing, the limestone is usually absent over the channels, thinning out irregularly and somewhat abruptly as they are approached. In one place also the limestone has been reduced by the solvent action of water, and there are small, collapsed caverns along the thinned edge of the limestone near the border of the channel. These features are best explained on the assumption of unconformity within the Pennsylvanian, the channels having been formed by erosion inaugurated some time after the deposition of the limestone, but previous to the time of deposition of some of the higher Pennsylvanian beds.

Quaternary System

CHARACTER AND THICKNESS OF THE DEPOSITS

Over a large part of the Edgington and Milan quadrangles the Quaternary or surficial deposits have an average thickness of nearly 100 feet; in some places the thickness is reported to be more than 200 feet. They consist of pre-Illinoian clay or sand, Pleistocene glacial drift or till, loess, and terrace deposits and Recent alluvium and dune sand deposits. All of these materials have been derived from indurated rocks partly through normal processes of weathering, partly through the grinding action of the glaciers, and in small part by the abrasive action of stream erosion. They have been transported and deposited by ice, wind, and water.

The greatest known thickness of the Quaternary deposits in the area is near the southeast corner of the NE. ¼ sec. 9, T. 16 N., R. 1 W., where a water well 220 feet deep was reported to have stopped on the top of bed rock.

In a water well put down near the middle of the S. ½ sec. 9, T. 15 N., R. 5 W., the top of the Pennsylvanian was said to have been reached at a depth of 200 feet, and in another well near the middle of the west side of sec. 23 of the same township, the Quaternary deposits were reported to be equally thick. Over most of the area of the quadrangles south of Mississippi and Rock rivers the thickness of the surficial deposits ex-

ceeds 125 feet. In 19 wells which were reported to have reached the top of the Pennsylvanian rocks the average thickness of the Quaternary deposits was 145 feet. In 58 other wells which did not reach the base of the Quaternary, the average thickness of the surficial materials penetrated was 125 feet.

PLEISTOCENE SERIES

DIFFERENTIATION OF DEPOSITS

The Pleistocene series is represented in the Edgington and Milan quadrangles by six of the different glacial and interglacial stages recognized in North America. The lowest bed of glacial drift that has been differentiated in the area has been found in only a few places, and is thought to belong to the Kansan stage. It is overlain by a dark clay or soil zone which corresponds to the Yarmouth interglacial stage. The upper glacial till that underlies almost the entire area is the Illinoian, and it is covered in many places by the Sangamon soil. The surface of the quadrangles is almost everywhere underlain by a bed of loess, a large part of which is thought to be of late Iowan and early Peorian age. In a few places in the valleys of Mississippi and Rock rivers are terrace deposits that are thought to be of Wisconsin age.

The topography of the glacial drift in this area is nowhere of the morainic ridge type. The surface is partially dissected ground moraine or drift plain that has been covered with a mantle of loess.

KANSAN TILL

The drift was derived from two different ice invasions, the earlier, Kansan, which invaded from the north or northwest, and the Illinoian, which advanced from the northeast. The deposits left by these two drift sheets are for the most part indistinguishable in character and appearance. Since the places are rare where the old Yarmouth soil bed that was formed on the surface of the Kansan till before the advent of the Illinoian glacier was left undisturbed by the latter ice sheet, and exposures of this Yarmouth soil horizon are still more rare, there are only a few places in the area where these two till sheets are exposed in superposition, or penetrated in well borings, so that they could be certainly differentiated.

An outcrop of the Kansan drift separated from the overlying Illinoian till by an old soil band representing the Yarmouth interglacial stage was seen in the banks of a ravine east of the center of the west line of sec. 8, T. 15 N., R. 1 W., about one and one-half miles southwest of

Sherrard. A section of the Pleistocene deposits exposed at this locality is given below:

Section of strata exposed in sec. 8, T. 15 N., R. 1 W.

	Thickness *Feet*
5. Loess, yellowish	18
4. Till, pebbly, yellow	12
3. Soil-like layer, dark, with a few pebbles	2
2. Till, pebbly, gray, leached	3
1. Till, pebbly, unleached	30+

In the foregoing section members 1 and 2 represent the Kansan till, member 3 the Yarmouth interglacial soil horizon, and member 4 the Illinoian till. A comparison of the pebbles in the two tills seen in the abovementioned exposure shows that among those measuring one-third of an inch in diameter, greenstone and limestone are more common in the lower till than in the upper; and dolomite pebbles are more common in the upper till than in the lower. A similar difference has been found to distinguish these two tills in eastern Iowa. The lower till in this exposure is doubtless the Kansan which has a wide distribution in Iowa and northern Missouri.

The lower till, members 5 and 6, in the log of the well near Seventh Avenue and Thirty-fifth Street, given in a preceding page, is also thought to represent the Kansan.

In the city of Davenport, immediately across the river from Rock Island, a weathered zone between two beds of till was formerly exposed along Eighth Street, between Myrtle and Vine. Leverett[1] has described the section of Pleistocene strata at this place as follows:

Section of Pleistocene strata formerly exposed in Davenport

	Thickness *Feet*
Loess	30
Till, reddish brown, leached and stained	2½ to 3
Till, brown, calcareous, crumbling readily	15
Clay, gummy, ash colored, with black streaks, apparently of humus (Yarmouth)	2 to 3
Till, brown, jointing in cubical blocks, color changing to grayish blue at 12 to 15 feet	25

The surface of the Kansan drift, the lowest till noted above, appears to have been subjected to erosion before the overlying till was deposited, as indicated by the fact that the surface of this lower drift declines 15 feet in a distance of 20 rods in passing toward the river valley.

A succession of Pleistocene deposits similar to those described in Davenport has been reported in the banks of the river in Muscatine, a short distance west of the Edgington quadrangle. A section of strata at this place, as reported by Leverett[2] is as follows:

[1]Leverett, Frank, The Illinois Glacial Lobe, U. S. Geological Survey Monograph XXXVIII, p. 45, 1899.
[2]Ibid., p. 47.

Section of Pleistocene strata exposed on Green Street, Muscatine, Iowa

	Thickness *Feet*
Loess, partly eroded	10
Silt, brownish black	1½ to 2
Soil, pebbly, black (Sangamon)	3
Till, brown, leached (Illinoian)	6
Till, brown, unleached, with many boulders in lower part (Illinoian)	12
Silt, calcareous (Yarmouth)	6 to 8
Till, calcareous, brown (probably Kansan)	10

A similar succession of Quaternary deposits is exposed along the branch of Eliza Creek, in the SW. ¼ sec. 14, T. 15 N., R. 5 W., in the Edgington quadrangle, where the following section was made:

Section of strata outcropping in the SW. ¼ sec. 14, T. 15 N., R. 5 W.

	Thickness *Feet*
5. Loess, yellowish brown	2 to 3
4. Till, pebbly (Illinoian)	19
3. Sand, more or less stratified	3 to 4
2. Loess-like silt	2½ to 3½
1 Till, pebbly, bluish (probably Kansan)	3

The lower till in the exposure last described probably represents the Kansan. A somewhat similar succession of strata exposed in the SW. ¼ sec. 26, T. 16 N., R. 5 W., may indicate deposits of two different glacial stages, as shown below:

Section of strata outcropping in the SW. ¼ sec. 26, T. 16 N., R. 5 W.

	Thickness *Feet*
Loess, yellowish brown	5
Till, pebbly (Illinoian)	11
Sand and gravel, irregularly bedded	2 to 3½
Till, pebbly (possibly Kansan)	4

It is somewhat uncertain whether the lower till in the last section represents an earlier glacial stage than the upper one, or whether the sand and gravel bed that separates the two drifts may have been spread over the lower till as an outwash deposit during a temporary withdrawal for a short distance of the margin of the single ice sheet. There is not sufficient evidence in such a bed of water-laid sand and gravel to prove whether it was deposited during an interglacial stage when the ice sheet had entirely melted from the region or during a temporary withdrawal of the ice front.

Compared with the younger Illinoian drift, the Kansan till is more bluish in color, where unweathered, and has a greater tendency to joint into cubical blocks when dry. It also contains a larger percentage of greenstone and limestone pebbles and fewer dolomite pebbles than are found in the upper or Illinoian drift in this region.

A count of the pebbles or different kinds of rock over one-third of an inch in diameter was made from the lower (Kansan) and upper (Illinoian) till at the exposure 1½ miles northwest of Cable, with the following results:

Kind of rock	Number of pebbles	
	Kansan till	Illinoian till
Quartz	11	5
Greenstone	10	5
Quartzite	4	4
Diabase	18	17
Granite	11	20
Limestone ($CaCO_3$)	14	6
Dolomite	0	4
Chert	15	16
Sandstone (Pottsville)	3	5
Shale (Pennsylvanian)	1	2
Chert, oolitic	1	4
Red crystalline rock	3	2

The Kansan ice sheet probably covered all of this region, but in many places the material it left was probably incorporated in the later drift sheet.

YARMOUTH INTERGLACIAL STAGE

Exposures showing a soil and weathered zone that was developed on the surface of the Kansan drift during the long Yarmouth interglacial stage have been described in connection with the discussion of the Kansan till. Such a soil and weathered zone presents the most convincing evidence of the intervention of a long interglacial stage between the time of deposition of the two drift sheets which it separates. Many other records of wells in the quadrangles report a dark-colored clay, or soil, or carbonaceous bed beneath the Illinoian drift, but in most places this bed immediately overlies Pennsylvanian strata, and hence it can not be determined whether the soil or peaty zone was developed wholly during Yarmouth time, or whether it represents a much longer period of pre-Illinoian soil or humus development.

PRE-ILLINOIAN DEPOSITS

A thickness of 5 feet of clay or silt underlying the Illinoian drift was exposed for a distance of nearly 100 yards in grading the wagon road a few years ago a short distance south of the center of sec. 12, T. 17 N., R. 2 W. This clay was homogeneous, and not laminated, resembling loess in texture and appearance. It contained shells of several species of air-breathing gastropods similar to those that occur in the surface loess of this region.

A similar deposit containing the same and other species of fossils was found in other places in the quadrangles; viz., on Thirty-ninth Street in Rock Island, between Seventh and Eighth avenues; on Thirty-eighth Street

between the same avenues; and in a well put down at the base of the bluff bordering Mississippi River 100 feet northeast of the crossing of Seventh Avenue and Thirty-fifth Street. In the bluff behind the well there is exposed a thickness of several feet of glacial till overlain by 40 feet of loess above the top of the curb. The log of this well is given below:

Log of well at the base of the bluff near Seventh Avenue and Thirty-fifth Street

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system—		
Pleistocene and Recent—		
Till, yellow (probably Illinoian)	5	5
Muck, black, with wood fragments (Yarmouth soil zone)	1	6
Till, brown, leached for 2 or 3 feet	7	13
Till, blue (Kansan)	4	17
Silt, loess-like, ash colored, calcareous, with loess fossils	8	25
Muck, black	4	29
Clay, greenish, residual, with many pebbles of local rocks, but no igneous fragments	5	34
Pennsylvanian system—		
Shale	..	..

In the exposure of these beds on Thirty-eighth Street the upper layer was laminated, as if waterlaid, and the underlying loess-like clay also contained many shells of pulmonate gastropods.

Another such bed of loess-like silt underlying the till, and resting directly upon Pennsylvanian rocks, is exposed along a ravine near the west side of sec. 7, T. 17 N., R. 1 W., where the following section was made:

Section of strata exposed along the west side of sec. 7, T. 17 N., R. 1 W.

	Thickness *Feet*
Loess	45
Soil, black	2
Till, yellowish brown (Illinoian)	12
Loess-like silt containing loess fossils	several feet
Sandstone (Pennsylvanian)	..

A good outcrop of this lower, loess-like clay is found in the east bluff of Mississippi River, in the SW. ¼ sec. 31, T. 16 N., R. 5 W., a section of which is given below:

Section of strata exposed in the east bank of Mississippi River, sec. 31, T. 16 N., R. 5 W.

	Thickness *Feet*
Loess	25
Soil, black	2 to 3
Till, mostly bluish (Illinoian)	90
Loess-like clay, with many fossils	12

The species of fossils collected from the lower loess-like silt at the outcrop along Mississippi River were identified some years ago by Dr. Dall, and are listed below:

Helicina occulta Say (very abundant)
Helicodiscus lineatus Say
Limnaea humilis Say, var.
Pyramidula perspectiva Say
Pyramidula striatella Auth.
Pupa armifera Say
Strobilops labryinthica Say
Succinea avara Say (less abundant than in the surface loess)
Succinea luteola Gould
Vitrea arborea Say?

In texture and general appearance this lower loess-like silt closely resembles the surface loess, and was probably deposited by the wind in a similar manner. It is probably rather widely distributed beneath the oldest drift in Rock Island County, and like the surface loess it is probably thicker near the east bank of the river than at a considerable distance from the larger streams.

ILLINOIAN TILL

Except along the streams where it has been removed by post-Illinoian erosion, the Illinois till underlies the loess over almost the entire area of the

FIG. 26.—Fine-grained water-laid sand, 50 feet thick beneath a few feet of Illinoian till in the SW. ¼ sec. 8 of Eliza Township.

quadrangles. It is a bluish-gray till which weathers to yellowish gray and contains sufficient sand to make it crumble more readily than the older, Kansan till. The sand and clay making up the main body of the till were

probably derived for the most part from local beds of shale and sandstone that had been rather deeply weathered before the glacier moved over the region. The coarser constituents of the Illinoian till consist in part of pebbles and boulders of crystalline rock transported from areas far to the north and northeast of the quadrangles, and in part of fragments of chert and limestone probably derived from Paleozoic limestones that outcrop in northern Illinois and southern Wisconsin.

The Illinoian drift is exposed in numerous places along the most of the larger streams of the area. It is thickest over the upland south of Mill

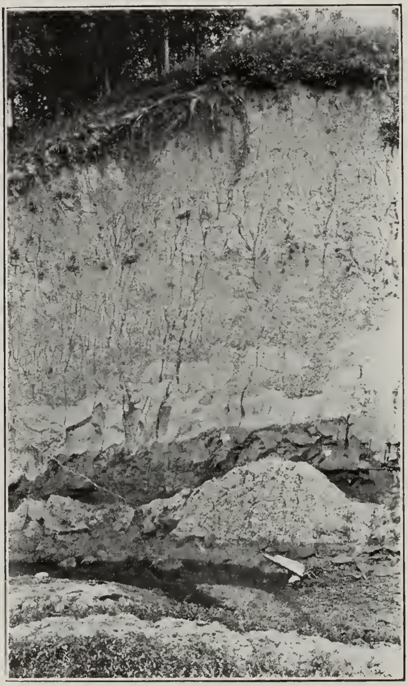


FIG. 27.—"Sea mud" or fine-grained sand underlying sand and gravel below Illinoian till in the NE. ¼ sec. 14, Eliza Township.

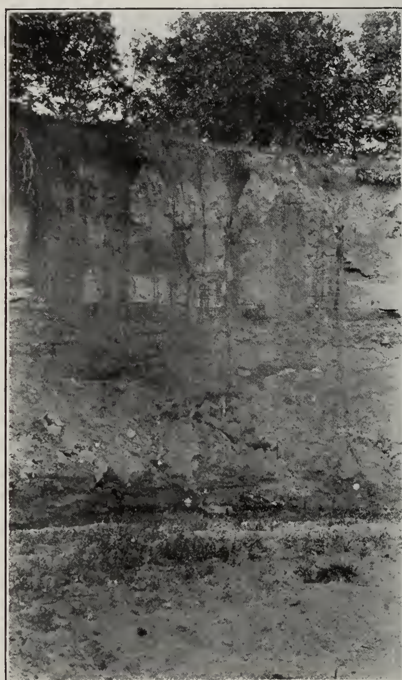


FIG. 28.—Sand and gravel below Illinoian till, exposed in the NW. ¼ sec. 26, T. 16 N., R. 5 W.

Creek and Copperas Creek in the Milan quadrangle, where many wells penetrate a thickness of 100 to 150 feet or more of Pleistocene deposits, the greater part of which is Illinoian till. The thickness is only slightly less on the upland south of Copperas Creek in the Edgington quadrangle and on the divide between this creek and the branches of Mississippi River, where many water wells pass through more than 100 feet of Pleistocene strata. The Quaternary deposits are in places 200 feet thick over the uplands in Eliza Township, in the southwest quarter of the Edgington quadrangle, but a greater thickness of loess and sand covers the hills in that region, and the

bed of sand underlying the Illinoian till is also thicker there than over the greater part of the quadrangles, so that the thickness of the Illinoian till is probably less than on the areas mentioned. In many places a bed of fine-grained sand (figs. 26, 27, and 28), known by the well drillers as "sea mud," underlies the Illinoian till; and a bed of sand and gravel is often present immediately above this drift. Thin lenses of sand or gravel are also present at one or more levels within the Illinoian drift in this region.

The thickness and relations of the Illinoian till in different places in the quadrangles are shown in the logs of the following wells:

Log of well at the McDonald (No. 92) School, near the SE. cor. sec. 30, T. 16 N., R. 1 W.

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system—		
Pleistocene and Recent—		
Loess, yellow	35	35
Till, dark blue, pebbly	95	130
Sand	9	139
Till, light blue	36	175
Sand, dirty	7	182

Log of well near SW. cor. sec. 2, T. 15 N., R. 3 W.

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system—		
Pleistocene and Recent—		
Soil, black	4	4
Loess, yellowish	15	19
Clay, black, with wood fragments	2	21
Till, blue, pebbly	26	47
Sand	60	107

Log of well in NE. ¼ sec. 8, T. 15 N., R. 3 W.

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system—		
Pleistocene and Recent—		
Soil and loess	18	18
Clay, black (muck or chip pile)	2	20
Till, blue, pebbly, with streaks of sand	30	50
Sandstone	2	52

Log of well in SE. ¼ sec. 28, T. 16 N., R. 4 W.

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system—		
Pleistocene and Recent—		
Clay, yellowish	20	20
Clay, black, with wood fragments	4	24
Till, blue, pebbly (hard pan)	52	76
Sand	5+	81+

Illinoian till is exposed in many places along the streams in both the Milan and Edgington quadrangles. An exposure along the wagon road up the river hill south from Jimtown School, in the NE. ¼ sec. 5, T. 16 N., R. 5 W., shows the following succession of strata:

Section of strata exposed near Jimtown School

	Thickness *Feet*
Loess, yellow, fossiliferous	22
Till, pebbly, bluish gray	35
Shale, dark and gray	43

In the south bank of Copperas Creek in the NW. ¼ sec. 19, T. 16 N., R. 4 W., there is exposed a bed of sand and gravel within the Illinoian till. A section of the strata outcropping at this place is as follows:

Section of strata exposed in the NW. ¼ sec. 19, T. 16 N., R. 4 W.

	Thickness *Feet*
Loess, brown, sandy	5
Till, sandy, with small pebbles	8
Sand and gravel	4 to 5
Till, bluish gray, pebbly, and sandy	10

Farther south, in the southwest quarter of the Edgington quadrangle, a bed of sand several feet thick, which probably corresponds to the 4-to-5-foot sand and gravel bed of the last section, is exposed in many places beneath a few feet of Illinoian till. A typical section of such an outcrop is given below:

Section of Pleistocene strata exposed in the SE. ¼ sec. 18, T. 15 N., R. 5 W.

	Thickness *Feet*
Loess	7 to 9
Till, pebbly, bluish gray	10
Sand, irregularly stratified	35

In an exposure about three-eighths of a mile west of the one last described, a thickness of 53 feet of irregularly bedded sand is present below 6 to 9 feet of Illinoian till. Whether another bed of till underlies the sand in this region could not be determined.

Another outcrop of Pleistocene strata on a branch of Copperas Creek in the SE. ¼ sec. 17, T. 16 N., R. 5 W., shows the following succession of deposits:

Section of Pleistocene strata exposed in SE. ¼ sec. 17, T. 16 N., R. 5 W.

	Thickness *Feet*
4. Loess, brown	4
3. Till, sandy and gravelly, in some places rather distinctly sorted	8 to 11
2. Till, brown, pebbly	16
1. Till, darker than No. 2 above, and separated from it by a rather definite plane; to water level	4

The lower till in the last section may represent the Kansan, as the plane of contact of this bed with the overlying brown till is sharp and conspicuous. However, the evidence regarding the different age is not conclusive.

A bed of sand and gravel probably deposited as an outwash when the Illinoian ice sheet was melting from the region is in many places present above the Illinoian drift, and beneath the loess. A representative exposure of such a sand bed was seen on a branch of Eliza Creek, near the NE. corner of sec. 22, T. 15 N., R. 5 W., the relations of which are as follows:

Section of Pleistocene deposits exposed near the NE. cor. sec. 22, T. 15 N., R. 5 W.

	Thickness *Feet*
Loess, yellowish brown, fossiliferous	15
Sand and gravel, and boulders up to 6 inches in diameter	2½ to 4
Till, bluish, pebbly	11

A succession of strata similar to those described in the last section outcrops near the SE. corner sec. 20, T. 16 N., R. 5 W., as shown below:

Section of Pleistocene strata exposed in sec. 20, T. 16 N., R. 5 W.

	Thickness *Feet*
Loess	13
Sand and gravel in irregular layers	3 to 5
Till, bluish gray, sandy, with pebbles	19

In a few places in the quadrangles a thin bed of gravel that appears to have been concentrated by the removal of the finer constituents of the till is present at the top of the Illinoian drift and beneath the loess. An exposure of such a bed of concentrated gravel was seen in the SW. ¼ sec. 28, T. 16 N., R. 5 W., as shown below:

Section of Pleistocene strata exposed in the SW. ¼ sec. 28, T. 16 N., R. 5 W.

	Thickness *Feet*
Loess	1½
Gravel, apparently concentrated from the till	1
Till, bluish gray, with pebbles	26

SANGAMON SOIL ZONE

The Sangamon interglacial soil or peat horizon is represented in this region by a band of black carbonaceous clay containing many plant remains and wood fragments. This dark-colored band contains such a large amount of imperfectly decomposed vegetable material that it is often reported by the well drillers as a "brush pile" or "chip pile" or "manure pile." It was developed as a soil or peat horizon on the surface of the Illinoian till during the interglacial stage that intervened between the withdrawal of the Illinoian

ice sheet and the deposition of the overlying loess. The relation of this Sangamon soil band to the Illinoian till is shown in some of the logs of wells given on the preceding pages to illustrate the stratigraphic relation of the Illinoian till. The Sangamon soil zone was reported in the logs of 61 wells in the quadrangles which are well distributed over the area. It lies immediately beneath the loess at depths ranging, with the varying thickness of the loess, from 12 to 30 feet.

A few additional logs of water wells in different parts of the quadrangles will show the character and distribution of the Sangamon soil in this area.

Log of well near middle of E. ½ sec. 12, T. 16 N., R. 5 W.

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system—		
Pleistocene and Recent—		
Clay, yellow: loess	17	17
"Chip pile"	3	20
Clay, blue, pebbly (Illinoian till)	22	42

Log of well near middle of W. ½ sec. 36, T. 17 N., R. 4 W.

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system—		
Pleistocene and Recent—		
Soil and yellowish clay (loess)	18	18
Clay, dark, with much plant debris (Sangamon soil)	2	20
Clay, bluish gray, pebbly (Illinoian till)	20	40

Log of well in SW. ¼ sec. 12, T. 15 N., R. 4 W.

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system—		
Pleistocene and Recent—		
Soil and yellow clay (loess)	15	15
Clay, dark, with wood fragments (Sangamon soil)	3	18
Clay, bluish, pebbly (Illinoian till)	42	60
Sand white	..	..

Log of well in SW. ¼ sec. 2, T. 15 N., R. 3 W.

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system—		
Pleistocene and Recent—		
Soil and clay	15	15
"Manure pile"	3	18
Clay, pebbly, blue	25	43
Sand	60	103

THE LOESS

Over all of the uplands in the Milan and Edgington quadrangles loess overlies the Illinoian drift and Sangamon soil to an average thickness of perhaps 25 feet. On the tops of the bluffs bordering the south and east sides of the larger streams the thickness in places reaches 40 or more feet. On Thirty-eighth Street, in Rock Island, it measures 40 feet. On the bluff at Black Hawk's Watch Tower, in the SE. ¼ sec. 14, T. 17 N., R. 2 W., the thickness is 55 feet. In the abandoned clay pit of the old National Clay Company, in the east bluff of the river, near Sears (fig. 29), the loess is 40 feet thick. In many places on the bluffs along the rivers the thickness exceeds 30 feet. At a distance from the rivers the thickness decreases, in many places being less than 20 feet.

FIG. 29.—Bluff of loess in old clay pit of Blackhawk Manufacturing Company, at Sears, Illinois. The loess here is somewhat sandy, and on weathering shows laminations. The holes were made by bank swallows.

As shown in well sections and outcrops the loess in most places lies just beneath the surface soil, and consists of uniformly fine-grained, unstratified, dust-like material that contains a small amount of calcium carbonate. Where it has been cut by streams or excavations it stands for a long time in almost vertical banks. In many places, especially on the hill tops where the deposit is thick, it contains indiscriminately distributed shells of air-breathing gastropods.

The following species identified by Dr. Dall, of the United States National Museum, are among the common fossils that occur in the loess of this region:

List of fossils occurring commonly in the loess of the Milan and Edgington quadrangles

Helicina occulta Say
Succinea luteola Gld.
Succinea avara Say
Succinea obliqua Say
Polygyra pennsylvanica Green
Polygyra thyroides Say
Pupa alticola Ingersoll
Pupa pentadon Say
Pupa muscorum Linn
Pyramidula striatella Anthony

The color of the loess on the hills is yellow grading to brown or gray, but on the level prairies, where the dark surface soil is deeper, the underlying loess is more gray in color. The difference in the color of the loess on the hills and on the prairies is not thought to be due to any difference in origin, but to differences in the degree of leaching and alteration by the action of organic matter.

In the SW. ¼ sec. 36, T. 17 N., R. 3 W., a thickness of 22 feet of loess containing many loess fossils and calcareous concretions, or loess Kindchen, is exposed. An iron-stained band, one inch thick, is present near the middle of this exposure, above which the deposit is slightly more brown than that below it. The tops of the hills bordering Mississippi River in the vicinity of Illinois City and farther east, are capped with loess. Near the foot of the hill in the SW. ¼ sec. 31, T. 17 N., R. 4 W., a sandy loess containing loess fossils is exposed to a height of 12 feet, and a similar loess deposit covers the drift all the way up this hill in the NW. ¼ sec. 6, T. 16 N., R. 4 W. A thickness of 35 feet of loess overlies the till along the wagon road near the middle of the N. ½ sec. 2, T. 16 N., R. 5 W. Over the western part of the Edgington quadrangle, as elsewhere in this region, loess usually covers the slopes at least part way down where they are steep, and entirely to the bottom where they are moderately gentle, as well as the tops of the hills, and the uplands. It is in places underlain by a sandy bed of reddish-brown color, which overlies the drift. At the base of this sand bed springs issue in many places in the banks of the streams.

Topographic features of the loess.—Near the river the ravines are deep with steep sides which give the impression of youthfulness to the topography. This is due to the thick deposit of loess on the hills where it tends to stand in nearly perpendicular banks.

In places along the bluff-lines facing north and west the loess has a characteristic relief peculiar to itself. As the bluff is approached from the upland the surface slopes gently toward the river until about one-fourth mile from the bluff, where the slope becomes reversed as a result of the piling up of the loess on the tops of the hills bordering the valley. There is formed in this way a rim of thick loess along the bluff behind which there may occur a shallow, poorly drained depression. Such a feature is conspicuous in the southeast part of Rock Island, and in the bluffs forming the south bank of Mississippi River for some distance east and west of Andalusia.

Another topographic feature of this deposit is the low, loess-covered margin of the uplands about a mile south of Milan, where there is an area about a mile long and a half a mile wide that is noticeably lower than the adjacent portion of the marginal upland. The loess that covers this lower area is somewhat coarser than the typical loess, and is in places obscurely stratified. A similar deposit occurs in the basal part of the loess on Seventh Avenue near Thirty-fifth Street, where it grades horizontally into typical loess.

Fig. 30.—Faults in the Pleistocene deposits near Augustana College in Rock Island. Three blocks are seen separated by two sharply marked vertical faults. The boulder clay can be distinguished from the overlying loess by the small parallel rills in the surface of the former. The nearest block has settled most. In it the base of the loess lies below the shadow of the telephone pole. In the middle block its base is covered by a growth of grass. The farther block has settled unequally so that the base of the loess is slanting.

Miscellaneous features of the loess.—Two other uncommon features occur in the loess in this area. In some places the lower part of the loess deposit is crumpled into small flexures about one foot in height and width, and in other places it is intricately faulted in such a manner as to

indicate that the deposit was frozen when the faulting occurred, as shown in figures 30 and 31. The larger of these faults extend downward into the underlying till, and some of the fissures have been enlarged and filled with water-laid sand.

The basal part of the loess shows considerable variation in physical characteristics. In many places there is a gradual change from a leached till below to a humus-filled loess or clay (Sangamon soil) above, in which fossil wood is common, and bones and teeth of elephants are occasionally found.

A carpal bone and part of a tooth of an elephant were found in such a deposit in the bluff near Twentieth Street, in Rock Island, and a piece of a tusk was found in the base of the loess at Sears. In other places the till changes upward into a ferruginous red zone which is overlain

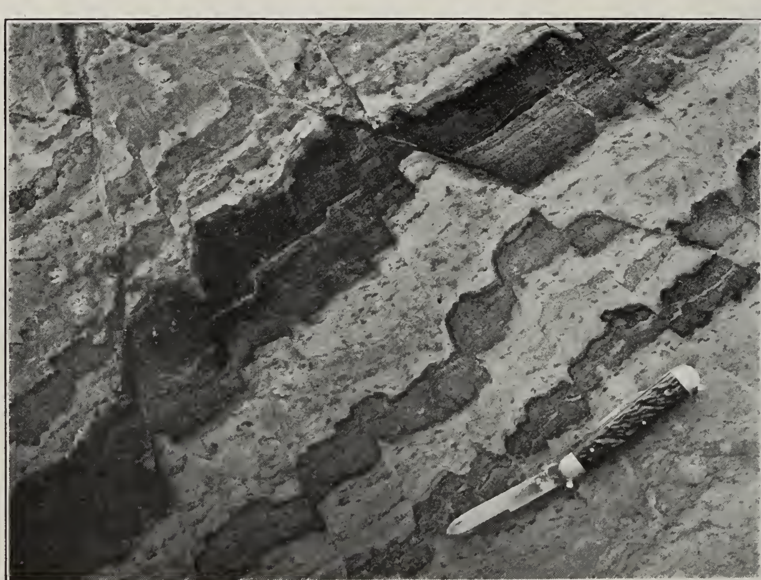


Fig. 31.—Small faults in the loess, in Rock Island.

by normal upland loess. In a few places there is an abrupt change from fresh, unleached till to typical loess above, the contact being sharply marked. An exposure of such a contact was seen in the south bluff of Rock River on the east side of the new wagon road that follows the east boundary of the Milan quadrangle. On the west side of the road at this place a thickness of 3 feet of gravel intervened between the loess and the till.

The geographic relation of the main deposit of loess in the upper Mississippi valley to the border of the area covered by the Iowan ice

sheet; its stratigraphic position beneath the Wisconsin drift, and above the Illinoian and older drifts from which it is in many places separated by a leached zone, peat, or soil bed, and by an erosional unconformity representing a long period; and the presence in the loess of fossil shells of air-breathing gastropods that lived under climatic conditions similar to those prevailing in the region today make it probable that conditions peculiarly favorable for the accumulation of loess occurred during the melting and for some time after the disappearance of the Iowan ice sheet. A small amount of loess overlies the Wisconsin drift in Illinois, and dust deposits somewhat resembling loess are now being formed. It is probable that a part of the original main deposit of loess has been shifted and reworked and that other dust has accumulated since the Peorian interglacial stage, but the total amount of such material is comparatively small.

There seems no doubt that the loess in this region, as elsewhere in the Mississippi valley, was deposited by the wind. This is shown by the following facts: (1) The deposit does not tend to level the inequalities of the surface, but mantles hills, prairies, and lowlands alike. (2) It is conspicuously thickest, and somewhat coarser in texture, on the tops of the hills bordering the south and east sides of the larger streams in places where the prevailing westerly winds, after following the stream valley for some distance, would be obstructed by the opposing banks, and compelled to drop a large part of their load as a result of their reduced velocity. (3) The loess differs from ordinary water-laid clay in the general absence of stratification. (4) It contains shells of air-breathing gastropods which, though exceedingly fragile, are commonly unbroken.

TERRACE DEPOSITS

In places along Mississippi and Rock rivers there are small terrace areas that are remnants of an alluvial filling in the valleys of these streams deposited during the stage of Wisconsin glaciation. The upper surface of the terraces lies 20 to 30 feet higher than the level of adjacent flood plains of the streams. The largest of these terrace areas is between one-fourth and one-half mile wide, and extends almost continuously near the east bank of Mississippi River from Twenty-eighth Street in Rock Island south as far as Sears. The material in this terrace consists mostly of sand, with some gravel, which is covered by a thin veneer of loess or silt. Sand and gravel pits were once extensively worked in this terrace deposit in the south part of Rock Island. Some sand and gravel in the south bank of the Government reservation above the west end of the power dam probably belongs also to this terrace deposit. The hill at Mount View School on the flood plain of Rock River in the N. ½ secs. 20 and 21, T. 17 N., R. 1 W., is a remnant of such a terrace that has been protected

from destruction by the river by an outlier of Devonian limestone at the east end. Some of the terrace sand at this place has been blown into small dunes.

In several places where creeks emerge on the alluvial plains of the rivers there are some remnants of deposits evidently formed in backwater in the valleys of the small tributaries. Such a small terrace fragment is present in the valley of Mill Creek one-half mile south of the river bluff, and in the west bank of Warren Creek, a short distance southeast of the center of sec. 29, T. 17 N., R. 2 W. A section of the backwater deposits at this place is as follows:

Section of terrace deposits at mouth of Warren Creek

	Thickness	
	Ft.	*In.*
Loess	1	6
Joint clay, dirty brown	2	..
Silt, yellow, moderately fine	3	..
Silt, yellowish gray, laminated	4	..
Silt, red	1	4
Silt, dark gray, irregularly laminated	..	8
Silt, pink and gray	..	8
Silt, gray, not distinctly laminated	3	6
Sand and gravel, yellow	3	..
Concealed by talus	8	..

A red and yellow silt similar to that exposed on Warren Creek outcrops under the railroad bridge over Turkey Hollow, in section 30 of the same township. At the latter place a part of the old terrace has been cut away by the present stream, the more recent alluvium overlying the terrace deposits unconformably. On the west side of a creek cutting the Mississippi bluffs in the NE. ¼ sec. 26, T. 17 N., R. 3 W., there occurs a terrace remnant several acres in extent, and a few small patches were noted in other places as indicated on the accompanying geological map of the quadrangles.

RECENT SERIES

ALLUVIUM

Deposits of alluvium are present along most of the streams in the quadrangles, the most extensive being along the valleys of Mississippi and Rock rivers. Smaller areas of alluvium border the channels of Edwards River and Mill, Copperas, Camp, and Eliza creeks, and the lower courses of smaller streams.

The thickness of the alluvial deposits is relatively thin, being less than 20 feet over the greater part of the bottom lands of this region, including those of the rivers. In one place, however, a short distance north of the southwest corner of the Edgington quadrangle, a water well was reported to have penetrated a thickness of 120 feet of alluvial sand and gravel without reaching bed rock, and a test boring put down on the flood plain of

Copperas Creek in the SE. ¼ sec. 16, T. 16 N., R. 4 W., passed through a thickness of 68 feet of unconsolidated surficial deposits above the Pennsylvanian rocks. A well on the flood plain of Rock River, in the NE. ¼ sec. 20, T. 17 N., R. 1 W., passed through 42 feet of sand and clay, and another well near the edge of the flood plain in the NE. ¼ sec. 30, of the same township penetrated 47 feet of alluvial material. The deposit in many places consists of sand and small pebbles, as near the SW. corner of sec. 22, T. 17 N., R. 2 W., where it is worked on quite a large scale for gravel. In other places, as along Edwards River, silt and clay are the principal constituents. While the greater part of the material of the flood plain deposits was laid down by the main streams that occupy the valleys and is fairly well sorted, on the margins of the valleys near the foot of the bluffs a considerable amount of poorly sorted talus, sheet wash, and alluvial-fan material is mixed with the alluvium where this valley plain rises in a short slope to the bluffs.

DUNE SAND

Although considerable sand is present in places over the flood plains of Mississippi and Rock rivers, in only a few localities has the sand been shifted by the wind to any important extent, and deposited in hills or dunes. A few small hills have been formed on the surface of the terrace on which Mound View School is located, in secs. 20 and 21, T. 17 N., R. 1 W., and in a few places on the Mississippi River flood plain in secs. 31 and 32, T. 17 N., R. 5 W. Sand or sandy loess caps several of the hills that border the east side of the valley of Mississippi River near the west side of the Edgington quadrangle, as in secs. 18, 19, 30, and 32, T. 15 N., R. 5 W., and in secs. 8, 18, 19, and 30, T. 16 N., R. 5 W. In sec. 8 of the latter township there are a number of small ponds surrounded by hills of sandy material. These ponds have not yet developed outlets, probably because the water readily soaks out through the porous sand that forms the higher parts of their banks.

STRUCTURE OF THE PALEOZOIC ROCKS

In the Milan and Edgington quadrangles the layers of rock are not quite horizontal, but in general they slope toward the south at the rate of a few feet to the mile. In an east-west direction the dip of the strata is more irregular and undulating; in some places the slope is toward the west, and in other places the direction of dip is eastward.

Structure of Pre-Pennsylvanian Rocks

The structure or dip of the Silurian and Devonian rocks appears to be somewhat different from that of the Pennsylvanian strata in this region. These older rocks dip in general toward the southwest at the average rate of about 9 feet per mile, as shown by the following observations:

In George Gray's well, one-fourth mile north of the southeast corner of sec. 10, T. 15 N., R. 3 W., the main water-bearing stratum of the Niagaran limestone lies about 332 feet above sea level, and in the well at Augustana College, about 14 miles north and 7 miles east of the former well, the corresponding horizon was reached at an altitude of 485 feet.

The southward descent of the Devonian rocks near the east border of the Milan quadrangle between Mississippi and Rock rivers is nearly 10 feet to the mile; but there is a rise of these rocks in the next 3 miles farther south. In the vicinity of Cable, near the southeast corner of the Milan quadrangle, the elevation of the top of the Devonian is about 513 feet above the sea. If the upper surface of the Devonian at Cable is the same horizon as that of the top of the Devonian exposed along Mississippi River, 15 miles farther north, a general southward dip of these strata at an average rate of only 3 feet per mile is indicated between Cable and Mississippi River.

In an east-west direction along Mississippi River the Devonian limestone dips toward the west across the Milan quadrangle, as shown by the fact that the top of the unfossiliferous Devonian limestone along Sylvan channel is about 580 feet above the sea level, while a short distance below Andalusia, 12 miles farther west, the altitude of this horizon of the Devonian is about 535 feet, making the average westward dip between these places about 4 feet to the mile. Six miles still farther west, in the SE. ¼ sec. 17, T. 17 N., R. 1 E., the corresponding level of the Devonian limestone occurs at an altitude of 585 feet, indicating a rise of the Devonian between these points of 50 feet, or about 8 feet to the mile. The elevation of the same rocks in the north bank of Rock River at the east border of the Milan quadrangle is about 545 feet, which is only 10 feet higher than 12 miles farther west, and about 40 feet lower than 18 miles farther west.

Near the south end of the quadrangles the dip of the Devonian strata is in general quite similar to that along Mississippi River farther north. A well near the middle of the east side of sec. 33, T. 15 N., R. 5 W., was reported to have reached the top of a thick limestone, which was probably Devonian, immediately beneath a bed of sand and gravel at an elevation about 445 feet above sea level. If the horizon of the top of the Devonian at this place corresponds with that of the top of the Devonian in the George Gray well 13 miles farther east, where the altitude is 457 feet, a westward dip of about one foot per mile is indicated between these places. Between the George Gray well and Cable, a distance of 10 miles, the top of the Devonian declines toward the west 56 feet, or about 5½ feet to the mile. Between the locality in the Edgington quadrangle in sec. 33, T. 15 N., R. 5 W., and the SE. ¼ sec. 20, T. 17 N., R. 1 E., a distance of about 16 miles, the southward slope of the top of the Devonian is 163 feet, or about 10 feet to the mile.

On this general dip some minor flexures are imposed. One of these, known from outcrops and well records, consists of an uplift or anticline 20 to 30 feet in height, exposed in the bed and banks of Mill Creek near the center of sec. 25, T. 17 N., R. 2 W., where for a short distance the unfossiliferous member (No. 2) of the general Devonian section rises in the left bank 5 feet above the bed of the creek. A short distance farther north this horizon of the Devonian suddenly disappears, and the overlying member, No. 3, of the general section is exposed in the banks of the creek for about one-fourth mile farther north, where these strata also disappear beneath the bed of the creek. A slight northward dip continues to Vandruff Island, where member No. 2 of the general Devonian section lies about at the level of low water in Rock River. The arch or uplift exposed along Mill Creek is also clearly indicated in the deep well at Milan, where the base of the Maquoketa lies 30 feet higher than it does in the wells in Rock Island 3 to 4 miles farther north. Member No. 2 of the Devonian general section is exposed near Oakdale, in the SE. ¼ sec. 18, T. 17 N., R. 3 E., a few feet above its normal altitude in this area, which suggests that the anticline indicated along Mill Creek and in the Milan well may continue through Oakdale about 20 rods north of the wagon bridge over the creek in the NE. ¼ sec. 27, T. 17 N., R. 3 W. A low anticline about 50 feet in width is exposed in the banks of a creek, and a short distance farther north a shallow syncline also crosses this stream. The axis of the anticline and syncline trends northwest-southeast in a direction nearly parallel with that of the uplift indicated at Milan and Oakdale.

The general southwestward tilting of the pre-Pennsylvanian rocks was not entirely accomplished before the Pennsylvanian rocks were deposited, for the latter strata are slightly affected by this movement. The elevation of the Herrin (No. 6) coal is usually lower in the localities where it outcrops a short distance east of the middle of the south side of the Edgington quadrangle, than that of the coal 17 miles farther east in the vicinity of Cable.

Structure of the Pennsylvanian Rocks

In the north and south parts of the quadrangles wherever the Herrin (No. 6) coal bed is present, the structure of the Pennsylvanian rocks can be determined fairly accurately by using this coal as the key horizon.

In the Edgington quadrangle the coal beds show a very slight southward dip between the places noted below: In the SE. ¼ sec. 20, T. 77 N., R. 1 E., the Herrin coal outcrops at an elevation of 658 feet. About 7 miles farther south, in the SE. ¼ sec. 21, T. 16 N., R. 4 W., the altitude of the coal is 654 feet. Seven miles still farther south, in the SE. ¼ sec. 28, T. 15 N., R. 4 W., the altitude of the Herrin coal is 650 feet. In the Milan quadrangle the lay of this coal bed is more irregular, and undulating, but the general southward dip is also slight. Near the middle of the north

line of sec. 32, T. 17 N., R. 1 W., the altitude of the Rock Island (?) coal is about 654 feet. Seven miles farther south near the NW. corner of sec. 4, T. 15 N., R. 1 W., the elevation of this bed is 629 feet. Four miles farther south, in the NE. ¼ sec. 29, T. 15 N., R. 1 W., the coal has risen again to 650 feet in altitude.

In an east-west direction the Rock Island (?) coal bed lies at an elevation of 658 feet in the SE. ¼ sec. 20, T. 77 N., R. 1 E., while 7 miles farther east, in the NW. ¼ sec. 16, T. 77 N., R. 2 E., the altitude of this bed is 660 feet, and about 13 miles farther east, at Coal Valley, the altitude is 648 feet. Near the south end of the quadrangles the Herrin coal outcrops on the SE. ¼ sec. 28, T. 15 N., R. 4 W., at an altitude of 650 feet. Three miles farther east, near the middle of the east side of sec. 24 of the same township, it has risen to 674 feet. Ten miles farther east, in the vicinity of Matherville, the altitude has decreased to 650 feet above sea level. While the general dip of this coal in any direction is slight, local dips of 25 feet in short distances are found. In mine No. 3 of the Coal Valley Mining Company at Matherville the Herrin coal lies at an elevation of about 630 feet, while about one mile southwest of this place near the middle of sec. 33, T. 15 N., R. 2 W., this coal outcrops at an altitude of about 650 feet. Another place where the altitude of the Rock Island (?) coal is low is in the shaft of mine No. 2 of the Coal Valley Mining Company at Sherrard, where it lies at an elevation of 612 feet, while at Cable about 3 miles farther south its altitude is 654 feet. In a test boring in the town of Cable the altitude of the Rock Island (?) coal is reported 30 feet higher than its elevation in an old coal shaft only 14 rods farther northeast. Whether this abrupt change in elevation is due to a fault or a steep dip could not be determined. In the coal mine at Sherrard the coal is undulating, a difference in altitude of 12 feet or more between the crests and troughs being common. The coal is usually thicker in the troughs, and thinner on the crests of these rolls. In mine No. 7 of the Alden Coal Company, the coal thins out in the east, north, and west directions, but maintains its thickness toward the south, as in the Sherrard mine. The main dip of this coal is toward the south and east.

Some of the minor local changes in the altitude of this coal are doubtless due to slight folding, but some of the irregularities are probably also due to the inequalities of the surface on which the vegetable matter that formed the coal bed accumulated, and to the unequal thickness of the vegetable matter of this bed from place to place, permitting unequal shrinkage when this vegetable matter was transformed into coal. The No. 1 and No. 6 coals are probably absent over the larger part of the middle portion of the Milan quadrangle, and over all but a very narrow belt one to two miles east of the central part and in the southeast corner of the Edgington quadrangle. On this account no attempt has been made to show the structure of the Pennsylvanian rocks in the quadrangles in this limited area by means

of contours on the coals, but the altitude of the coal is shown by figures at the different localities in the area where it has been found in outcrops, shafts, or borings.

GEOLOGIC HISTORY

Imperfection of the Record

A considerable part of the geologic history of these quadrangles from the beginning of the Paleozoic era to the present can now be deciphered from the rocks exposed at the surface or encountered in borings in this region. The succession of events from the beginning of the Paleozoic era to the end of the Pennsylvanian epoch can be sketched in a broad way from the records preserved in the ancient rocks of this and adjacent areas. The times of submergence, the sources of the invading seas, and the general topography of the region during the times of emergence can be described with a good degree of assurance. The history of Mesozoic and Tertiary time has not been preserved in sedimentary deposits in this immediate region, but can be inferred from what is known of the events of this time in other parts of the continent, where such deposits have been studied. The record of many of the principal events of the Quaternary period has also been preserved in the quadrangles in legible form. Many other facts in the geologic history of the quadrangles can be safely inferred from the results of studies in other areas in this general region, for the processes that operated in the quadrangles affected also an extensive province around them.

During the Paleozoic era the surface of Illinois was intermittently submerged by an epicontinental sea, the shores of which migrated widely and almost continuously, though the rate at which they shifted varied greatly from time to time. Since Paleozoic time this surface, with the exception of a small area in the southern part of the State, has been continuously above sea level, and subjected to the agents of erosion which are constantly acting upon the lands.

Paleozoic Era

CAMBRIAN PERIOD

At the beginning of Paleozoic time the surface of Illinois had probably been above the sea for a long time, and had been worn by erosion to a nearly level plain. This planed, almost level, surface of Algonkian rocks doubtless forms the floor beneath the Paleozoic strata over the entire State, and extends far beyond its borders on every side. During the latter part of the Cambrian period a sea advanced from the southwest over this region, and deposited the sand, clay, and calcareous material that make up the sandstones, shale, and limestone of the upper Cambrian or Croixan (Potsdam) series in the Mississippi Valley. Of these sediments sandstones pre-

dominate, the entire series having a known thickness of 868 or more feet. A few deep borings in the State have penetrated these upper Cambrian rocks to a depth of 1,100 feet without reaching the top of the Algonkian.

ORDOVICIAN PERIOD

The sediments deposited in this region during Ordovician time consist mainly of limestone and dolomite, but at certain times important deposits of sand and mud accumulated over extensive areas. The oldest division of this system is the Prairie du Chien limestone or dolomite, which was accumulated in rather clear seas and has a thickness in the quadrangles of 668 to 811 feet. After a break in sedimentation this limestone deposition was followed by the St. Peter sandstone, which doubtless also underlies the entire State except in a few small patches where it has been removed by erosion. Its thickness in this area ranges from 50 to 204 feet. Above the St. Peter sandstone were deposited in this area the Platteville and Galena limestones, 320 to 370 feet thick, after which a withdrawal of the sea put a stop to deposition. During the next submergence this region, like the greater portion of Illinois, received deposits of mud, sand, and limy sediment which now compose the shales, sandstones, and shaly limestones of the Maquoketa formation. The average thickness of this formation in deep wells in the area was 204 feet.

SILURIAN PERIOD

This region was land during early Silurian time, but in middle Silurian time the area comprised in the Edgington and Milan quadrangles was covered by a clear sea, and received calcareous deposits known as the Niagaran limestone or dolomite, which ranges in thickness from 215 to 375 feet.

DEVONIAN PERIOD

After a long emergence the sediments that accumulated above the Niagaran in this region consist of limestones, of late middle Devonian age, which have a thickness in the quadrangles of about 140 feet. This was followed in Upper Devonian time by the widespread deposition of dark mud containing great numbers of fossil spores, of lycopodaceous plants. This is known as the Sweetland Creek shale formation, which was probably laid down over almost the entire State. It is well exposed along Sweetland Creek, in Iowa, in the northwest quarter of the Edgington quadrangle, and has been identified in well borings in many places in Illinois.

MISSISSIPPIAN PERIOD

This region was a land surface between the deposition of the upper Devonian strata and the lowermost Mississippian. During the Mississippian epoch the southern part of the Mississippi valley was extensively submerged.

Although no rocks belonging to this epoch have been found in place in the quadrangles, yet fragments of chert occurring in the basal conglomerate of the Pennsylvanian system contained molds and casts of fossils characteristic of early or middle Mississippian rocks, indicating that more or less of these strata were originally deposited over the area.

PENNSYLVANIAN PERIOD

POTTSVILLE TIME

For a long time after the middle Mississippian submergence this region was a land surface which became much trenched by erosion channels and developed considerable relief before the Pennsylvanian sea invaded the region. Upon this unevenly eroded surface the early Pennsylvanian rocks were laid down when the sea next covered the area. Slight warping preceded the invasion of the Pennsylvanian sea which transgressed older formations over extensive areas in the northern part of the Mississippi valley. In early Pennsylvanian time sedimentation was restricted to a rather narrow area in the Eastern Interior coal field of Illinois and northwestern Kentucky. As a result of further warping movements and erosion the sea was permitted to gradually spread northward, and extend farther eastward and westward. In this gradually enlarging basin were accumulated the sand and mud and limy clay which now make up the sandstone, shale, and impure limestone of the Pottsville formation. Layers of vegetal material interbedded with the other sediments indicate the existence of marshes at different times. The vegetal material that accumulated in these marshes now forms irregular layers or lenses of coal, ranging from thin films to beds which locally reach a thickness of 3 to 5 feet. The seas that from time to time covered this area during the Pottsville epoch were so shallow that some of the higher places were probably not entirely covered during the time of submergence, and a slight lowering of the strand line resulted in the emergence of the higher areas. Hence deposition was not uniform over this region, and frequent changes in the character of the sediment and local erosional unconformities occur within the Pottsville beds.

CARBONDALE AND MCLEANSBORO TIME

During the Carbondale and McLeansboro epochs this immediate area remained above the sea a large part of the time. However, in late Carbondale time a marsh in which the vegetal material accumulated that later became the Herrin coal, existed in places over the area; and during early McLeansboro time there was a great transgression of the sea, permitting the deposition of the limestone containing *Girtyina*, and higher strata.

Post-Pennsylvanian Deformation

Deposition of Pennsylvanian time was closed by widespread movements which resulted in the uplift of the Appalachian Mountains in the east and the Ouachita and Ozark Mountains to the southwest, and the further uplift

of the La Salle anticline in Illinois. Attending these larger movements there were formed also the faults and minor folds that affect the Pennsylvanian rocks in different parts of the State. These movements permanently banished the sea from the region.

The rocks of the Edgington and Milan quadrangles were not greatly disturbed by these deformations, no faults having been found in the area, and the tilting and slight flexing of the strata that occurred at that time are so gentle that they are scarcely distinguishable from original irregularities of deposition. The general altitude of the surface was probably considerably increased, the region being elevated from near sea level to a position a few hundred feet above it.

Mesozoic Era

After the elevation and deformation that occurred near the close of the Pennsylvanian period, the areas that had received deposits of sediment at different times during the Paleozoic era were subjected for a very long time to continuous denudation. Erosion has progressed almost without interruption from that time to the present, although at different times it has been accelerated by slight uplifts, and at others it was probably retarded by a more or less close approach to peneplanation.

Cenozoic Era

TERTIARY PERIOD

Some time before the close of the Tertiary period the surface of the greater part of Illinois and adjacent regions had been reduced to a nearly level plain, as shown by the fact that the surface beneath the Quaternary deposits is quite level except where narrow valleys were cut in late Tertiary and early Quaternary time.

Near the end of the Tertiary period there occurred a general uplift of the land which quickened erosion and caused the streams to deepen their valleys. Well borings show that many such rock valleys 100 to 200 feet deep, now filled with drift, occur in Illinois, and a few such buried valleys have been found in the Milan and Edgington quadrangles. The valley of Mississippi River, near the southwest corner of the Edgington quadrangle, was cut at least 120 feet below the level of the present flood plain, and the valley of Copperas Creek, in the NE. ¼ sec. 16, T. 16 N., R. 4 W., was about 65 feet below its present level.

The maximum relief of the preglacial surface was at least 234 feet, but except in the deepest valleys it did not exceed 80 or 90 feet.

QUATERNARY PERIOD

PLEISTOCENE EPOCH

At the beginning of the Quaternary period, the surface of the Milan and Edgington quadrangles was much like the present surface, but dif-

ferent from it in one important particular. The topographic features of that time had been developed solely by erosion, whereas those of the present surface were in part produced by deposition of drift, and in part by the subsequent erosion of these deposits by the present streams.

Kansan time.—Relatively early in the Pleistocene epoch, during the Kansan stage of glaciation, an ice sheet developed at the north and spread broadly over the upper Mississippi basin, invading western Illinois from the Iowa side. After a long period of glacial occupation the ice melted away, leaving a thick mantle of clay, sand, pebbles, and boulders over the area it had covered.

Yarmouth time.—A change of climate from some cause or causes resulted in the melting of the Kansan ice sheet, which was followed by a long interval during which the climate did not greatly differ from that prevailing in the region today. During this interglacial stage, known as the Yarmouth, the surface of the Kansan till was covered with vegetation, and after a long time a soil was developed in the upper part of the till, and the glacial deposits suffered considerable alteration and erosion.

Illinoian time.—The next event of importance was the advance over the region of the Illinoian ice sheet which came from the northeast, centering in Labrador. As it moved forward it gathered up much of the material left by the Kansan ice sheet and mixed it with other debris brought from the north. In some places, however, it overrode without greatly disturbing the older drift, or even the soil which had developed upon it, but buried it just as it was. When the Illinoian glacier melted it left over the surface a thick bed of till which completely buried the hills and valleys developed by the streams during Yarmouth time, leaving the surface more nearly level than before.

Sangamon time.—Upon the surface of the nearly level drift plain left by the Illinoian glacier, new drainage lines were gradually developed, and over the more level areas the organic matter from successive generations of plants accumulated to such an extent as to form a carbonaceous soil (the Sangamon soil) which was in places peaty and contained large amounts of undecomposed plant remains. Percolating ground water leached and otherwise weathered the upper few feet of the underlying till. On the slopes where erosion was active, organic matter was not allowed to accumulate, but there was developed in places a thin bed of gravel which was concentrated at the surface by the removal by sheet wash and erosion of the fine constituents of the till.

Iowan and Peorian time.—The invasion of the Iowan glacier was not recorded by deposits of till in this immediate area. However, after the development of the present stream channels and the weathering of the upper portion of the till were well advanced, conditions arose in late Iowan and early Peorian time which favored the accumulation of extensive deposits

of dust. This dust or loess was spread over the surface of the Illinoian drift sheet, covering the Sangamon soil and peat, the concentrated gravels, and over the leached and eroded surface of the Illinoian till where the soil, peat, and gravel were absent. Later, dust transportation diminished, and the erosive processes again became dominant. The carving of valleys continued without interruption until the Wisconsin time, when they had reached almost their present forms.

Wisconsin time.—After the close of the Peorian interglacial time, ice of the Wisconsin stage invaded northern and eastern Illinois and spread westward to a position within 50 miles of the area under discussion. The headwaters of Rock River and of other tributaries of the Mississippi in this region were covered by the Wisconsin ice sheet. The water liberated from the melting ice and loaded with glacial debris, followed these stream valleys westward from the ice sheet, depositing in their channels, and along the Mississippi into which they discharged, large quantities of sand and gravel. After the Wisconsin glacier melted from the region, the streams, in adjusting their channels to the reduced volume and load, cut down into the coarse materials they had recently deposited, and developed flood plains at lower levels. The greater part of this old filling has been removed, but in a few places patches of this material have escaped erosion and stand several feet above the level of the present flood plains as remnants of terraces, which indicate the height to which the stream valleys had been filled.

RECENT EPOCH

In the Recent epoch the altitude of this region is not known to have changed in any important way. The principal event has been the removal of a part of the material deposited during the Pleistocene epoch. During this time the streams have been widening their valleys and forming broader flood plains.

MINERAL RESOURCES

The principal mineral resources of the Milan and Edgington quadrangles comprise coal, shale and clay, limestone, sand and gravel, and water. To these may be added the soil which is the chief source of wealth in the area.

Coal

The Milan and Edgington quadrangles lie near the northwest corner of the eastern interior coal basin (fig. 13), and in the part of this basin where the Rock Island and Herrin coals, exist only in patches.

COALS OTHER THAN THE ROCK ISLAND AND HERRIN BEDS

In many places two or more coal beds besides the Rock Island and Herrin coals are known to be present in this area. These coals are thin, usually ranging from a few to 18 inches thick, and in only a few places is the thickness of one or more of them known to reach 24 to 30 inches. The distribution of these coals is as irregular as their thickness, some of them

being absent and others present in different outcrops and test borings less than one mile distant from each other.

One of the thicker of these coals occurs near the base of the Pennsylvanian, but it is not persistent at this horizon. In the abandoned clay pit of the National Clay Company, at Sears, a coal 2 feet thick occurs about 5 feet above the Devonian limestone. In the log of a test boring in the SE. cor. SW. 1/4 SE. 1/4 sec. 28, T. 16 N., R. 4 W., a coal bed 19 inches thick is reported 17 feet above the Devonian limestone at an elevation of 569 feet, and another boring one-half mile farther northwest found a coal 29 inches thick 12 feet above the top of the Devonian, at an altitude of 550 feet. In a boring one-half mile east of the one last mentioned a coal 21 inches thick was found 35 feet above the Devonian limestone at an elevation of 510 feet. Another coal, reported 38 inches thick, occurs 14 feet higher, at an altitude of 524 feet. In another boring one-half mile south of the last, a coal 18 inches thick was reported 17 feet above the Devonian at an altitude of 490 feet; another coal, 8 inches thick, occurs about 61 feet higher, and a third bed 25 inches thick, is reported 50 feet still higher, at an elevation of 603 feet.

The following data on the coals penetrated in four test borings around the border of a single quarter section of land will illustrate the very variable distribution and thickness of these coals:

In the log of a boring on the NW. cor NW. 1/4 SE. 1/4 sec. 28, T. 16 N., R. 4 W., a coal 29 inches thick was reported about 14 feet above the Devonian limestone at an altitude of 549 feet; another coal 26 inches thick was found at an elevation of 645 feet; another 11-inch bed occurred at an altitude of 655 feet; and another 8-inch coal was present at 679 feet. Another boring one-half mile east and one-fourth mile south of the last, passed through a coal 21 inches thick, lying 35 feet above the Devonian, at an altitude of 509 feet; another bed 38 inches thick at 526 feet altitude; a 4-inch coal at 542 feet altitude; a 20-inch bed at 634 feet altitude; and a 6-inch coal at an elevation of 650 feet above sea level. A boring one-fourth mile south of the last passed through 18 inches of impure coal 17 feet above the Devonian, at an elevation of 489 feet; an 8-inch bed at 550 feet altitude; a 25-inch coal at an elevation of 603 feet; a 6-inch coal at 622 feet altitude; and a 5-inch coal at 647 feet elevation. A fourth boring one-fourth mile west of the last found 19 inches of coal above the Devonian, at an elevation of 569 feet, and an 8-inch coal at an elevation of 650 feet.

These variations are shown in the accompanying columnar sections (fig. 32).

As indicated above, it is not probable that any of these thin coals are peristent over very large areas, and the thicker beds appear to be somewhat more restricted in distribution than the thinner ones. In a few places near, or at, their outcrop in the banks of the tributaries south of Mississippi River, one or another of these coals has been worked on a small scale, by drifts

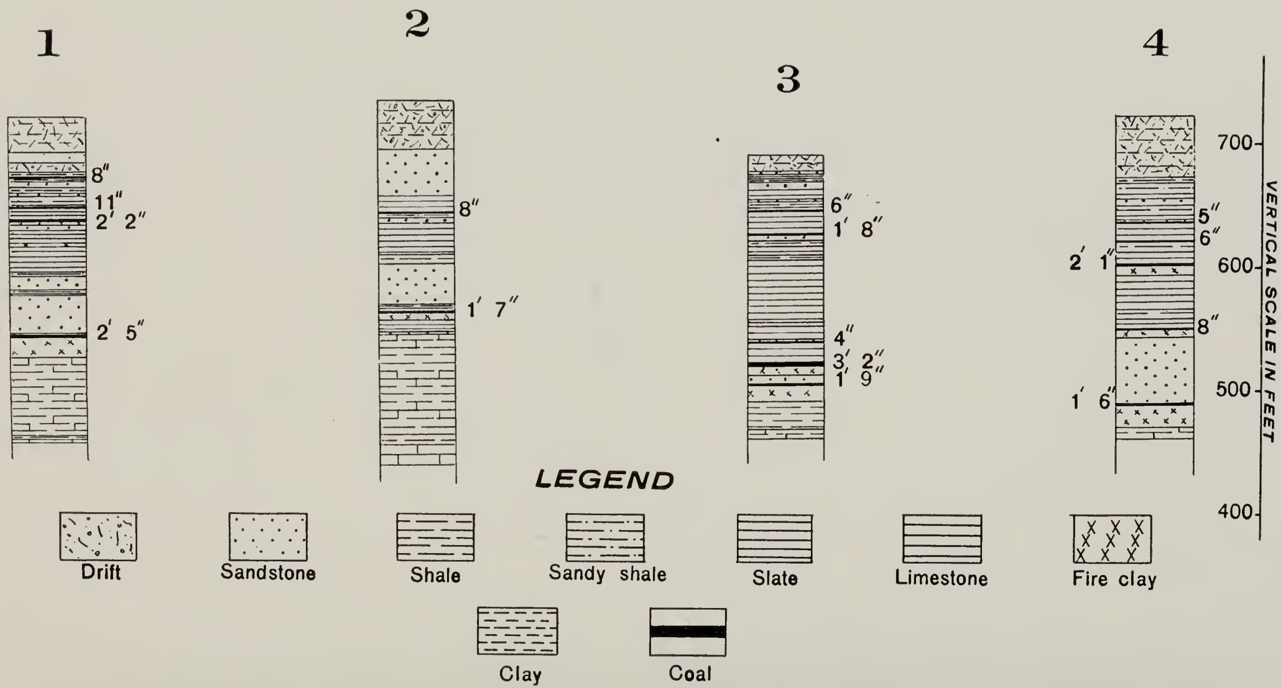


FIG. 32.—Columnar sections showing the variations in the number and thickness of the various coals penetrated in borings near Andalusia and Illinois City.

or strippings, for local use. Such old workings are most common along some of the streams between Illinois City and Andalusia where the different coals thicken and thin within short distances. They reach thicknesses of 18 to 28 inches in the places where they have been worked, and the range of elevation of the various beds locally mined in this part of the area ranges from 575 to 714 feet. On account of the irregularities in the thickness and extent of these coals it seems improbable that they will ever become of more than local interest and importance.

ROCK ISLAND (NO. 1) (?) AND HERRIN (NO. 6) COALS IN THE MILAN QUADRANGLE

The Herrin (No. 6) bed is the only coal that has been worked on a commercial scale in the quadrangle. This bed is known to be present over the greater part of the southeast quarter of the Milan quadrangle, to which area its commercial exploitation has been limited. Logs of borings in sec. 32, T. 17 N., R. 1 W., and in sec. 5, T. 16 N., R. 1 W., indicate that over a small area one of these coals may be present in that part of the quadrangle, from which it probably extends east towards Coal Valley, where outcrops are known to occur. In these areas the Herrin (No. 6) coal is usually overlain by a dark, impure, in places siliceous limestone known to the drillers as "blue rock," which is easily recognized in borings or outcrops. A small drift formerly worked in sec. 32, T. 17 N., R. 3 W., shows an unusual thickness of very impure coal, 24 to 42 inches, overlain by a thin-bedded sandstone, at an altitude of 642 feet. This coal may possibly represent the Rock Island bed, but there is no way of certainly determining that it does. A coal was formerly drifted on in the bank of the creek in the NE. ¼ sec. 2, T. 16 N., R. 3 W., at an altitude of 660 feet. On the old dump at this locality were found septaria with cone-in-cone structure, and containing shells of a small *Productus* and other brachiopods, which may represent the dark limestone that normally overlies the Herrin (No. 6) coal. However, it is certain that the horizon of numerous large septarian concretions with cone-in-cone structure, so well developed along Coal Creek and other streams farther west, belongs to a level approximately 30 feet lower than that of the Herrin coal bed. North of Mississippi River in the northwest quarter of the Milan quadrangle, these coals have been recognized in a few places in secs. 9, 11, and 15, T. 77 N., R. 2 E.

It is thought that the coal is absent over the larger part of the Milan quadrangle south of Mississippi River, outside of the area above mentioned. It may have originally been deposited over a greater or less part of this area in which it is now absent, having been removed by pre-Pleistocene erosion. Preglacial erosion was strong in parts of the quadrangle, as is shown in the fact that all of the Pennsylvanian strata were removed in places

near Mississippi and Rock rivers, and Mill Creek where the Devonian limestone lies immediately beneath the drift. Records of water wells in parts of sec. 9, T. 16 N., R. 2 W., also show that in those localities all of the Pennsylvanian rocks were removed before the glacial drift was deposited. It seems probable, however, that the Rock Island coal was never present over parts of this area since Pennsylvanian outcrops and well records are known up to altitudes higher than that of the Rock Island coal bed farther east, north, or south in which neither this coal nor the dark limestone that usually overlies it are present.

ROCK ISLAND (NO. 1) AND HERRIN (NO. 6) COALS IN THE EDGINGTON QUADRANGLE

The Herrin (No. 6) coal outcrops in several places along Camp Creek and Little Camp Creek, and probably underlies the larger part of the south half of the southeast quarter of the Edgington quadrangle. It may also extend to a greater or less distance eastward into the Milan quadrangle. The Herrin coal bed is thought to be absent over almost all of the other parts of the Edgington quadrangle south of Mississippi River. It outcrops in a few places in sec. 30, T. 17 N., R. 3 W., and one or two small outcrops of dark, impure limestone belonging to a horizon immediately above the No. 1 or No. 6 coal occur in the south bank of Copperas Creek, in secs. 21 and 22, T. 16 N., R. 4 W. This limestone was underlain by a thin coal, possibly the Herrin bed, which lies at an altitude of about 654 feet above sea level. Both the coal and the limestone occur at this locality only in small patches, as is shown by the fact that logs of test borings made in these sections, and in secs. 27 and 28, adjacent on the south, show no trace of the dark limestone or the Herrin coal. North of Mississippi River this coal and the overlying dark limestone outcrop in the SE. ¼ sec. 20, T. 17 N., R. 1 E., and in a few other places in the Iowa part of the Edgington quadrangle. The Herrin coal is known in outcrops and test borings in too few places to justify plotting the rock structure of the quadrangles on the stratum. The altitude of this coal in the places where it is known is shown by figures on the map, Plate II.

As in the Milan quadrangle, the Herrin coal probably accumulated over a larger area than that which it underlies at present. From such areas a part of it may have been removed during the long post-Pottsville-pre-Pleistocene interval of erosion, during which in places all of the Pennsylvanian strata were denuded, as in the SE. ¼ sec. 33, T. 15 N., R. 5 W., and in several places in the northern part of the quadrangle, where the Quaternary strata rest on Devonian limestone. It is not at all improbable also that coal never accumulated over a large part of the area in which it is now absent in the quadrangle, or, if it did, it was removed by contemporaneous

erosion indicated by more or less local intra-Pennsylvanian unconformities.

There is little doubt that the Herrin coal occurs in many places where it is not now known, for a considerable part of the area of the quadrangles has not been thoroughly tested. This coal probably underlies considerable parts of Perryton and Preemption townships, between the areas in which it is known in the southeast part of Edgington and that on the southeast part of the Milan quadrangle. It is probably absent over Eliza and Drury townships, and a sufficient number of test borings and sections of outcrop are known in Buffalo Prairie Township to show that the coal is there present in only a few small patches. In Edgington, Bowling, the north half of Rural, and the greater part of Black Hawk and Andalusia townships, the Pleistocene deposits are deep, and doubtless cover preglacial lowlands where all but isolated remnants of this coal were eroded away before the drift was deposited. If such remnants are found in these townships, they will probably have a poor cover, and prove of little value on account of difficult mining conditions.

CHARACTER OF THE HERRIN (NO. 6) COAL

In the mines where the Herrin coal bed has been worked, the thickness varies from 2½ to nearly 5 feet. It is a black, and rather soft coal, having a dark-brown streak. Where it is normally developed it is in a single bed which contains a parting with some impurities a short distance below the middle part. The details of this coal and associated strata at different localities where the bed could be well studied are shown below:

Section of Herrin coal in mine No. 3 of Coal Valley Mining Company at Matherville

	Thickness *Feet*
Limestone, dark	7+
Shale, black, fissile, fossiliferous	¼
Coal, with much mineral charcoal in thin bands, and showing indistinct impressions of leaves and other parts of plants. Sulphur occurs disseminated in chunks or small particles in the lower part of the coal, and in thin leaf-like layers in the upper	3½ to 5

Section of Herrin bed in mine No. 7 of the Alden Coal Company, at Matherville

	Thickness *Ft.*	*In.*
Limestone, dark	7+	..
Shale, dark	3	2
Coal: upper bench	1	4
Coal: middle bench	..	10
Coal: lower bench, with a little marcasite near the top	2	6
Shale, with marcasite and imprints of *stigmaria*	1	..
Underclay	3	6

Section of the Herrin coal in the mine of Dougherty Bros., near Boden

	Thickness Ft.	In.
Limestone, dark	14	..
Shale, black, fissile	2	..
Coal	2	10
Shale, or bony coal, brown, containing marcasite	..	2
Underclay, gray	2+	..

MINES AND MINING METHODS

All of the commercial coal mines operated in this area are in the southeast quarter of the Milan quadrangle. Three commercial mines are in operation in this quadrangle, and another was opened in 1917 about one-fourth mile south of the border of the quadrangle, along the Rock Island Southern Railroad. Besides these shipping mines, several local mines are worked during the autumn and winter months to supply local trade. The most of the mining is done on the room-and-pillar method. The haulage is by mule-tail rope or electric or gasoline motors. The roof conditions are good, and the flow causes little trouble. Below is given a list of the shipping mines, the average thickness of the coal in these mines, the depth to the bottom of the Herrin coal bed, and the altitude of the base of the coal in each mine.

TABLE 36.—*Shipping mines in the Milan and Edgington quadrangles 1920*

Name	Depth to bottom of Herrin coal	Thickness of Herrin coal bed	Altitude of base of Herrin coal
	Feet	*Inches*	*Feet*
Alden Coal Co., mine No. 7	92	34-54	598
Coal Valley Mining Co., mine No. 3	69	36-60	624
McCraney Sand and Gravel Co	56	46	654

Besides the shipping mines listed above, about 10 local mines in the quadrangles are worked during a few months of each year.

CHEMICAL ANALYSES

Samples of coal were collected from several of the mines in the area and the results of analysis are shown in Table 2. The analyses for which "C" numbers are given in the second column of the table, are republished from Illinois Mining Investigations Bulletin 3.

TABLE 37.—*Analyses of mine samples from the Edgington and Milan quadrangles*

Not exactly indicative of commercial output

Lab. No.	File No. *	Date 1912	County	Coal bed	Proximate analysis of coal 1st: "As recd," with total moisture. 2nd: "Dry" or moisture free.				Sulphur	CO_2	B. t. u.	Unit coal
					Moisture	Volatile matter	Fixed carbon	Ash				
5338	C19 0227a	......	Mercer.......	6	13.23 Dry	40.29 46.43	37.20 42.88	9.28 10.69	4.37 5.04	.41 .47	11104 12797	 14641
5339	C19 0227a	8/12	Mercer.......	6	15.24 Dry	37.66 44.44	35.73 42.15	11.37 13.41	4.80 5.66	1.47 1.73	10353 12214	 14478
5340	C19 0227a	8/12	Mercer.......	6	15.15 Dry	39.06 44.44	38.48 42.15	7.31 14.41	3.30 5.66	.17 1.73	11252 12214	 14478
5363	C19 0227a	8/12	Mercer.......	6	14.97 Dry	38.27 46.03	37.07 45.36	9.69 8.61	3.75 3.89	.33 .19	9637 13260	 14760
5364	C19 0227a	8/12	Mercer.......	6	14.46 Dry	40.42 44.99	35.33 43.61	9.79 11.40	4.23 4.95	.69 .43	10780 12749	 14712
5365	C19 0227a	8/12	Mercer.......	6	14.07 Dry	39.95 47.24	34.01 41.32	11.97 11.44	4.55 4.94	.78 .59	10525 12603	 14551
5359	C18 0227	8/12	Mercer.......	6	14.58 Dry	39.49 46.49	36.82 39.59	9.11 13.92	5.60 5.29	.15 .91	10894 12247	 14604
5360	C18 0227	8/12	Mercer.......	6	15.07 Dry	38.14 46.23	37.44 43.09	9.35 10.68	4.85 6.56	.34 .18	10790 12754	 14642
5361	C18 0227	8/12	Mercer.......	6	14.10 Dry	39.60 44.91	36.73 44.01	9.57 11.02	3.92 5.71	.23 .38	10956 12705	 14618
5371	C17 0104	8/12	Mercer.......	1?	17.75 Dry	39.50 48.03	34.61 42.08	8.14 9.89	5.53 6.72	.86 1.05	10435 12687	 14373
5372	C17 0104	8/12	Mercer.......	1?	17.50 Dry	38.78 47.00	33.66 40.80	10.06 12.20	4.51 5.46	.29 .35	10238 12409	 14372
2775	0528	11/09	Rock Island..	...	17.30 Dry	38.25 46.25	36.25 43.82	8.17 9.87	5.10 6.16	....	10578 12791	 14533
1758	0536	8/08	Rock Island..	...	15.36 Dry	35.64 42.05	37.03 43.70	12.07 14.25	6.45 7.61	....	10178 12010	 14673

*Analyses having the same file number are from the same mine.

SHALE AND CLAY

Shale, loess, and alluvial clay have been used in this region in the manufacture of clay products. Of the shale, two beds have been used. The lower one lying near the base of the Pottsville was worked a few years ago by the Black Hawk Clay Manufacturing Company, at Sears, in making the better grades of pressed brick and building brick. A thickness of about 24 feet of shale was dug and mixed with a considerable percentage of the overlying loess as the raw material.

In the vicinity of Illinois City a bed of white shale 5 to 7 feet thick was formerly worked for white pottery, and used by four plants near Illinois City in the manufacture of jugs, crocks, and jars. Considerable quantities of this shale were also hauled to Fairport, and used in the manufacture of similar products. This bed of white clay lies about 35 feet above the upper zone of thin clay-iron stone concretions at an altitude of about 695 feet. It appears to be of limited distribution, this white phase especially not having been recognized outside of a small area, less than one square mile in extent, in the vicinity of Illinois City. This shale has not been utilized for a number of years.

The Davenport Brick and Tile Company operates an up-to-date clay plant at Buffalo, Iowa, across the river from Andalusia. Shale from the basal part of the Pottsville mixed with the overlying loess is the material from which hollow building block, sidewalk brick, paving brick, building brick, sewer pipe, and drain tile are manufactured.

For several years Mr. Hans Paulson has operated a brick yard on Twelfth Street road in South Rock Island. The more common grades of building brick are made from the surficial clays, about 34 per cent of loess being used in the mix with about 66 per cent of the underlying blue clay, a vertical face of 26 feet being dug.

A few years ago Olaf Atkinson and Mr. Richmond in Rock Island, and August Raistens in Moline, operated plants for the manufacture of the more common building brick, using surficial clays as the raw material. In recent years work in these plants has been discontinued.

Limestone

The only limestone of commercial importance that outcrops in the quadrangles is of Devonian age, and is exposed along the rivers in the north part of the area.

The Moline Stone Company formerly operated a large quarry in the limestone from the lower part of the Devonian, in Moline. The stone was crushed, and large quantities sent to the Rock County Sugar Company at Janesville, Wisconsin, for use in refining sugar. Considerable quantities of crushed stone were also shipped to various places within a radius of 100 miles, for use in concrete and road building.

The Cady quarry and Swan Tropp quarry in Moline have taken out a large amount of Devonian limestone for use in the city and adjacent territory.

In the bank of the river at Sears considerable limestone has been quarried for Government use in connection with the canal and locks, and other improvements in that vicinity. Limestone has also been quarried in the bank of the river south of Sylvan Island, and near the east end of Rock Island, for Government use.

Large quantities of limestone are quarried by the Linwood Quarry Company at Linwood and the Dorese Brothers Crushed Stone Works at Buffalo. The larger part of this stone is sold for riprap, or crushed for concrete and other purposes. It finds market in many places between Rock Island and Kansas City.

Sand and Gravel

Sand suitable for plaster and cement is abundant in many places along Mississippi and Rock rivers, and along the channels of several of the larger creeks in the quadrangles. Large quantities of both sand and gravel have been taken from a large pit worked by the Rock Island Southern Railroad Company on the flood plain of Mississippi River near the SE. cor. sec. 21, and the SW. cor. sec. 22, T. 17 N., R. 2 W. A vertical face 12 to 14 feet high has been worked in this pit for a distance of about 20 or more rods. The material consists mostly of small gravel mixed with coarse sand. This is an important source of gravel which is sorted from the sand by screening. Large amounts of sand are hauled from the channels of Rock Creek and Mississippi River for use in plaster and concrete in Rock Island and Moline.

Portland Cement Material

The chief raw materials required for the manufacture of Portland cement are limestone and clay or shale. The limestone should be relatively free from such undesirable impurities as dolomite, chert, and pyrite. The clay or shale should not contain much sand, pyrite, or gypsum.

Limestone in sufficient quantities and apparently of requisite purity is available, convenient to the Chicago, Rock Island and Pacific Railroad, in the vicinity of Sears and Milan, in the northeast part of the Milan quadrangle. This limestone is of Devonian (upper Wapsipinicon and lower Cedar Valley) age; a working face of 20 to 40 feet could be in places developed.

Shale of Pennsylvanian age that appears to be suitable for Portland cement material is exposed in the old clay pit of the Black Hawk Manufacturing Company only a short distance from the limestone outcrops. While tests and analyses of these materials should be made before their suitability for Portland cement manufacture could be certainly determined, yet these deposits appear promising and their ready accessibility and nearness to the railroad would seem to warrant an investigation of this locality on the part of anyone looking for available material for Portland cement purposes.

The limestone worked in the old Cady quarry in East Moline also seems to be relatively pure calcium carbonate, and suitable clay or shale could doubtless be found at no great distance away.

Possibilities of Oil and Gas

No definite and systematic testing for oil or gas has been done in this region. The churn-drill coal borings serve to test the rocks for oil and gas to the depth these borings penetrate the Pottsville strata, and the deep water wells in the area furnish information regarding the presence of oil and gas in strata as far down as they explore. Owing to the lack of any single, easily recognized key stratum in the Pennsylvanian rocks, the altitude of which could be determined from outcrops in borings in many places over the entire area, it has not been possible to present a structure map of the quadrangles showing the lay of the rocks in different places, and the areas where small domes arches, or synclines might be present. A few small structural features are known, as the low anticline extending in a northwest direction from near the center of sec. 25, T. 17 N., R. 2 W., probably passing through Milan and across Mississippi River near Oakdale. This arch is 20 or more feet in height, and presents somewhat favorable oil structure. A small dome appears to be indicated by the altitude of the Herrin coal bed in sec. 24, Duncan Township, and sec. 19 of Perryton. What the eastward extension of this convex structure may be can not be determined by the explorations made up to the present time.

The rise of the Rock Island coal from Sherrard, where its altitude is about 612 feet above sea level, to Cable, where its elevation reaches 654 feet, indicates a dome or anticlinal structure in the vicinity of Cable of sufficient magnitude to warrant testing, if any oil tests were to be made in this vicinity.

Another small dome is indicated southwest of Matherville. The altitude of the Herrin coal at Matherville is about 630 feet, while about one mile southwest of this place the coal rises to 650 feet.

However, it should be remembered that the presence of oil depends on several factors besides structure, so there is a large element of uncertainty regarding the presence of oil even where the structure appears favorable.

GAS IN GLACIAL DRIFT

Small quantities of gas have been reported from a few water wells in the quadrangles. Gas was reported in a well about one-fourth mile east of the center sec. 35, T. 17 N., R. 2 W. In another in the NE. ¼ sec. 35, T. 16 N., R. 5 W., gas was found in a bed of sand or sandy clay at a depth of 85 feet. In another well in the NW. ¼ sec. 36 of the same township gas is said to have been found at two levels, respectively 80 and 119 feet below the surface. In all of these cases the gas occurred in porous beds of sand or sandy clay enclosed in the drift. In such cases the gas was doubtless derived from the decomposition of relatively small amounts of organic matter that was buried in the glacial drift, and it can not be

expected to occur in such quantity as to be commercially important. Such gas-bearing beds of sand or gravel enclosed in glacial drift have no necessary connection with oil or gas accumulations in the deeper rock strata, nor does the presence of gas in the glacial drift furnish any indication of the presence of oil or gas in the deeper, hard rock strata of the region in which it occurs.

Soil

Five of the types of soil differentiated in the soil survey of the Illinois Agricultural Experiment Station are found in this area. These are: (1) black clay loam, found on the poorly drained prairies; (2) brown silt loam, found on the undulating uplands; (3) yellow silt loam, found on the hilly areas; (4) brown loam characteristic of the flood plains or bottom lands; and (5) sand soil, found in places along the flood plains, and crowning the hills in places along the east bank of Mississippi River.

Like all others, these soils have been formed by geologic processes, to which they owe to a considerable extent their texture, their chemical and physical composition and their fertility. The character of the soil at any place depends on the character of the rock or rocks from which it was derived and on the conditions and forces to which it has been subjected.

In the Milan and Edgington quadrangles the black clay loam has been formed from the loess under conditions of poor drainage which permitted the residual, imperfectly decomposed plant debris to accumulate in the soil. Probably imperfect drainage and humid climate are the chief factors concerned in the development of the dark color of this soil.

The brown silt loam has been developed under conditions similar to that of the black clay loam, except that erosion was a little more active in the area where it occurs, which gave to the surface a little better drainage, and prevented the accumulation of the dark carbonaceous residual plant material to an equal degree.

The yellow silt loam was formed in places where erosion has been still more effective than in the areas of brown silt loam, and where the dark, imperfectly decomposed plant debris is removed by erosion and leaching as rapidly as it is formed.

The brown loam soil differs in origin from the type described above in that it receives from time to time accessions of new material. It lies on the flood plain within reach of high water, so that a thin film of sediment is deposited more or less uniformly over it at every time of overflow. The resulting soil is usually somewhat sandy, and loose textured.

The sand soil is found only over small areas of flood plains, or on the hills bordering the east bank of Mississippi River. This soil is granular, porous, and thin, and is the least fertile of the soil types in the area.

Water Resources

SHALLOW WELLS AND SPRINGS

An abundant supply of excellent water for domestic use can be obtained at shallow depths throughout this area. Rain and snow water is readily absorbed by the loess and percolates downward until it reaches the underlying comparatively impervious boulder clay. Much of it accumulates at the top of this clay, though near the borders of the upland a part moves laterally until it reaches the surface on the valley sides, where it issues as springs. A part percolates down into the boulder clay, commonly reaching and saturating lenses of sand which are in many places enclosed in the till.

WELLS IN THE GLACIAL DRIFT

Many of the farm wells obtain water from the base of the loess, which until recent years has been one of the important sources of water in the shallow wells on the uplands. On account of the general lowering of the ground-water level during the last fifty years, this source of water supply has been gradually weakened, and wells have more and more been drilled into sands lying within the glacial drift. Many wells from 80 to 140 feet deep obtain their water from sand and gravel beneath the boulder clays. Wells of this kind are common in the areas of deep drift in Black Hawk, Bowling, Edgington, Preemption, Perryton, Buffalo, Prairie, Drury, Eliza, and Duncan townships. Where the sand or gravel bed lying within or beneath the till is more than a few inches thick, it yields an abundant supply of water for farm wells.

WELLS IN HARD ROCK

Where abundance of water is not obtained in the porous beds associated with the drift, it is sometimes found in the Pottsville sandstones, either those near the base of the formation or those occurring at higher levels. Borings into the Pottsville are often put down to the top of the Devonian limestone.

The sandstones of the Pottsville are so irregular in their development and distribution that in some places well drillers have been obliged to drill a distance of 50 to 100 feet into the Niagaran limestone before obtaining a strong water supply. The upper part of the Niagaran limestone is usually porous, and seldom fails to furnish a generous supply of water. This water-bearing horizon is found about 475 feet above sea level in the northern part of the area, but declines to about 325 feet above sea level, or lower, in the south part of the quadrangles. On low places over the Mississippi flood plain the Niagaran limestone has yielded an artesian flow.

The shallowest source of water for flowing wells in this region is the Galena dolomite. The water from this horizon usually has a strong odor of hydrogen sulphide, and in most wells that have penetrated to or below

this horizon the water has been cased off to prevent its mingling with the water from deeper sources. The only well known to be supplied from this horizon alone is the deep well at Linwood, the flow from which is known as the "sulphur springs."

The St. Peter sandstone is the most reliable source of good deep-well water in the quadrangles. The original head of the water from the St. Peter sandstone in the quadrangles was about 645 feet above sea level, but in recent years this head has been reduced by the many wells that have been bored into the St. Peter sandstone in the cities of Rock Island, Moline, and Davenport, so that at present it does not much exceed 580 feet. The water from wells tapping the St. Peter sandstone will probably flow everywhere in the flood plains of the Mississippi and Rock rivers in this region. The supply of water from the sandstone is abundant, and the quality excellent, as shown by the analyses made by the State Water Survey, Table 38.

The St. Peter sandstone is the main source of water supply in the Atlantic Brewery well, in Rock Island, in the paper mill well in Moline, and in the city well in Milan.

The deepest artesian water supply in this region is from the sandstones of Upper Cambrian age. The head of this water is higher than that of the St. Peter sandstone. A test made in the well of the Rock Island Brewing Company on Elm Street in Rock Island, in 1905, showed that when the well was cased down to 1,604 feet the water rose to a height of 596 feet above sea level. By the use of an air-lift this well has yielded 450 gallons per minute. The water from the Cambrian sandstone in the Prospect Park well in Moline and the Mitchell and Lynde well in Rock Island was somewhat more salty than that coming from the St. Peter sandstone. From a well said to be 2,000 feet deep, on the edge of the flood plain of the north side of sec. 2, T. 16 N., R. 5 W., water flows constantly in a stream nearly three inches in diameter. The altitude of the top of the well is 549 feet. This water is also strongly mineralized and not good to drink. In this region the head of the water from the Cambrian sandstone is not so high now as it was when the first wells were put down into the formation.

Surface-water Supplies

The supply of surface water in this area is abundant for all ordinary purposes, but the water contains so much sediment, and other impurities that filtering is necessary before it is safe for domestic use. Since good well water is easily available everywhere in the region, stream water has not been much utilized except by the larger cities, which require large amounts. The city of Moline obtains its water supply from Mississippi River, the water being filtered through Jewell filters, lime, and iron also being used in the treatment. Sanitary analyses of the unfiltered and filtered river wa-

ter from which the Moline city supply is obtained were made by the State Water Survey. The results are shown in tables 39, 40, and 41.

TABLE 38.—*Mineral analyses of St. Peter sandstone water from wells in the Milan and Edington quadrangles*

Town	Rock Island (3rd Avenue and 14th Street)	Rock Island (1st Avenue and 6th St.)	Moline (Power Plant)	Moline	Moline	Milan (4th and West Sts.)
Owner	Moline Plow Co.	Rock Island Plow Co.	Deere Plow Co.	Deere and Co.	Dr. R. C. J. Meyer	City
Depth of well . . . . . *feet*	1581	1404	1467	1490	1028	1157
Depth of casing . . . . . *feet*	....	....	250	850	....	700
Rate of pumping *gals. per min.*	....	....	78	36	....	100
Date sample was collected	July 24, '11	April 25, '11	April 23, '12	April 23, '12	Feb. 20, '07	Aug. 8, '18
Determinations made (parts per million)						
Potassium	12.4	30.	27.8	16.1	....	....
Sodium	338.3	318.4	297.7	228.	304.6	351.5
Ammonium	2.	.4	2.1	2.3	1.7	1.9
Magnesium	21.	21.	25.3	30.5	28.5	21.18
Calcium	46.7	50.	57.2	71.5	58.6	41.31
Iron	.1	2.	1.6	.8	.3	1.9
Alumina	1.6	1.2	.0	1.2	6.	0.3
Nitrite	....	....	.0	....	....	....
Nitrate	.4	2.2	.0	....	.5	.35
Chlorine	205.	295.	280.	270.	300.	185.2
Sulphate	378.5	244.8	313.5	189.3	307.8	371.8
Silica	7.2	18.8	6.4	5.6	6.4	14.6
Bases	5.2	2.8	5.6	4.	....	....
Hypothetical combinations (parts per million)						
Potassium nitrate	.6	3.6	....	....	....	....
Potassium chloride	23.2	54.5	53.	30.7	....	....
Sodium nitrate	....	....	....	....	.7	.5
Sodium chloride	320.1	444.1	420.5	421.5	495.1	305.9
Sodium sulphate	560.2	362.2	407.1	190.9	337.	549.6
Sodium carbonate	20.2	59.8	....	....	....	120.3
Ammonium sulphate	....	....	7.7	8.4	....	....
Ammonium carbonate	5.3	....	....	....	....	4.9
Magnesium sulphate	....	....	41.1	65.7	100.4	....
Magnesium carbonate	72.7	72.7	58.9	65.8	28.4	73.4
Calcium carbonate	116.6	124.8	142.8	178.5	146.3	103.2
Iron carbonate	.2	....	3.3	1.7	.6	3.8
Iron oxide	....	2.	....	....	....	....
Alumina	1.6	1.2	....	1.2	6.	.3
Silica	7.2	18.2	6.4	5.6	6.4	14.6
Bases	5.2	2.8	5.6	4.	4.4	....
Total	1183.1	1145.9	1146.4	974.	1125.3	1177.1
Hypothetical combinations (grains per U. S. gallon)						
Potassium nitrate	.03	.21	3.09	....	....	....
Potassium chloride	1.35	3.18	....	1.79	....	....
Sodium nitrate	....	....	....	....	.04	.03
Sodium chloride	18.67	25.90	24.51	24.58	28.87	17.71
Sodium sulphate	32.68	21.12	23.74	11.13	19.64	31.18
Sodium carbonate	4.09	3.49	....	....	....	6.98
Ammonium sulphate	....	....	.44	.48	....	....
Ammonium carbonate	.31	....	....	....	....	.29
Magnesium sulphate	....	....	2.44	3.83	5.88	....
Magnesium carbonate	4.24	4.24	3.43	3.84	1.66	4.25
Calcium carbonate	6.80	7.28	8.32	10.40	8.53	5.81
Iron carbonate	.01	....	.19	.09	.03	.22
Iron oxide	....	.11	....	....	....	....
Alumina	.09	.07	....	.06	.34	.01
Silica	.42	1.06	.37	.32	.37	.85
Bases	.30	.16	.32	.23	.26	....
Total	68.99	66.82	66.85	56.75	65.62	68.01

TABLE 39.—*Sanitary analyses of water from Mississippi River*
City Supply of Moline, Illinois
Filtered

Serial number	Date of collection	Appearance			Residue on evaporation	Chlorine	Oxygen consumed	Nitrogen as:				Alkalinity	Bacteria per c.c.	Colon bacillus		
								Ammonia								
		Turbidity	Color	Odor				Free	Albuminoid	Nitrites	Nitrates			10 c.c.	1 c.c.	0.1 c.c.
13841	12/18/05	Decided	.4	3 Earthy	162.	1.5	9.10	.068	.240	.000	.28	86.6	....	1+	2−	2−
13919	1/15/06	do	.2	.000	155.	1.5	7.45	.096	.192	.001	.360	107.2	238	1−	2 ?	1+1−
14026	2/19/06	do	.2	.000	183.	2.0	7.4	.112	.136	.003	.32	128.6	1,690	......	2+	2−
14232	4/16/06	Clear	.1	2 Earthy	104.	1.1	3.8	.080	.176	.005	.80	40.0	1,550	1−	2+	2−
14367	5/14/06	do	.00	.000	127.	2.0	5.2	.064	.174	.006	.20	52.0	7	1−	2−	2−
14787	8/13/06	Slight	Muddy	.000	164.	2.0	7.85	.024	.184	.000	.48	104.7	61	1 ?	2+	2−
14953	9/10/06	Clear	.00	.000	214.	2.0	8.3	.024	.192	.000	.200	109.4	13	?	1+1−	2−
15302	11/ 5/06	do	.3	.000	107.	1.0	7.85	.032	.160	.002	.320	73.0	2,400	1+	2−	2−
15398	11/26/06	do	.6	.000	130.	3.0	7.80	.056	.160	.000	.440	82.0	270	1+	1+1−	1+1−

TABLE 40.—*Sanitary analyses of water from Mississippi River*
City Supply of Moline, Illinois
Unfiltered

Serial number	Date of collection	Appearance			Residue on evaporation	Chlorine	Oxygen consumed	Nitrogen as:				Alkalinity	Bacteria per c.c.	Colon bacillus		
		Turbidity	Color	Odor				Ammonia: Free	Ammonia: Albuminoid	Nitrites	Nitrates			10 c.c.	1 c.c.	0.1 c.c.
13840	12/18/05	Decided	.6	3 Earthy	216.	1.5	12.9	.088	.272	.000	.28	136.0	....	1 ?	2+	......
13918	1/15/06	do	.4	.000	245.	1.0	11.65	.088	.240	.001	.440	88.0	1,000	1+	1+	1+
14025	2/19/06	do	.5	.000	264.	2.5	11.25	.112	.216	.003	.24	171.4	8,100	1−	1+	1+
14231	4/16/06	Distinct	Mud	2 Earthy	202.	1.7	6.00	.080	.280	.001	.04	62.0	12,500	1+	1 ?	2−
14366	5/14/06	Decided	.4	.000	391.	1.5	14.75	.176	.428	.006	.24	93.0	4,800	1+	2+	2−
14786	8/13/06	do	Mud	.000	508.	2.0	16.00	.024	.560	.050	.27	128.0	320	1+	2+	2−
14952	9/10/06	do	do	2 Earthy	384.	2.0	15.9	.016	.480	.010	.230	124.8	900	1 ?	2+	2+
15299	11/ 5/06	do	.8	.000	195.	1.0	13.9	.056	.264	.002	.320	117.1	*133,000	1+	1+	1+
15300	11/ 5/06	do	.8	.000	192.	1.0	9.95	.056	.312	.002	.240	119.0	*272,000	1+	2+	1+
15301	11/ 5/06	do	.8	.000	200.	1.0	13.7	.064	.344	.002	.280	126.7	*690,000	1+	2+	2−
15397	11/26/06	do	Mud	.000	235.	2.0	12.35	.048	.280	.002	.680	130.6	8,200	1−	2−	2−
15399	11/26/06	do	do	.000	221.	2.0	12.65	.040	.280	.001	.440	126.7	5,500	1+	2+	1−
15400	11/26/06	do	do	.000	201.	2.0	12.7	.080	.264	.001	.440	126.7	6,700	1−	2−	2+

*First set of plates were lost, second set plated after samples had stood at room temperature for ten hours

TABLE 41.—*Results of an analysis of the mineral content of water from Mississippi River*
City Supply of Moline, Illinois
Laboratory No. 14366 and No. 14367, July 3, 1906

Ions		Parts per million		Hypothetical combinations		Parts per million		Grains per U.S. gal.	
		Raw 14366	Filtered 14367			14366	14367	14366	14367
Sodium	Na	5.9	8.7	Sodium nitrate	$NaNO_3$	1.5	1.2	.09	.07
Ammonium	NH_4	.2	.1	Sodium chloride	NaCl	2.5	3.3	.15	.19
Magnesium	Mg	11.0	4.7	Sodium sulphate	Na_2SO_4	13.9	21.9	.81	1.27
Calcium	Ca	28.7	23.3	Ammonium sulphate	$(NH_4)SO_4$	.7	.4	.04	.02
Iron	Fe	6.1	....	Magnesium sulphate	$MgSO_4$	1.1	5.9	.06	.34
Alumina	Al_2O_3	12.4	1.5	Magnesium carbonate	$MgCO_3$	37.4	12.1	2.18	.71
Nitrate	NO_3	1.1	.9	Calcium carbonate	$CaCO_3$	71.6	58.2	4.18	3.39
Chloride	Cl	1.5	2.0	Iron carbonate	$FeCO_3$	12.6	....	.73	....
Sulphate	SO_4	10.8	19.8	Alumina	Al_2O_3	12.4	1.5	.72	.09
Silica	SiO_2	104.1	31.7	Silica	SiO_2	104.1	31.7	6.12	1.85
Bases	....	42.0	.4	Bases	....	42.0	.4	2.45	.02

The city of Rock Island also obtains its water supply from Mississippi River. The sanitary and mineral analyses of the water from the Rock Island supply gave results similar in a general way to those of the Moline city water, as would be expected from the short distance between the intake of these cities.

Water Power

Water power is developed by a dam across a branch of Rock River between Milan and Sears. Much greater amounts of water power could be made available on Mississippi River in this region but no effort has been made to develop power from this source.

GEOLOGY AND MINERAL RESOURCES OF THE AVON AND CANTON QUADRANGLES

By T. E. Savage

OUTLINE

ILLUSTRATIONS

TABLES

INTRODUCTION

Location and Importance of the Area

The district described in this paper embraces one of the important areas in which the Springfield (No. 5) coal is mined in the State. It is quadrangular in shape, approximately 26 miles long in an east and west direction, and a little more than 17 miles wide, and contains about 450 square miles.

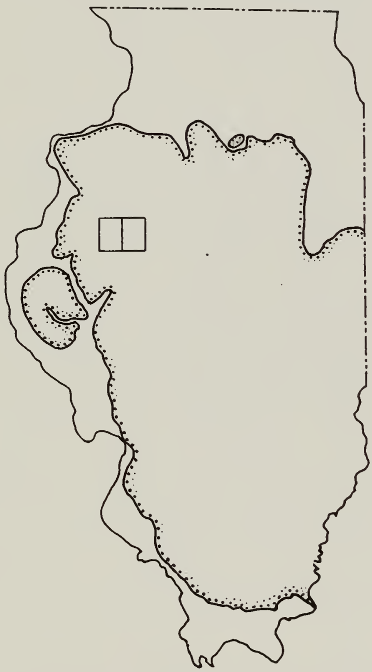


Fig. 33. Map showing the location of the Avon and Canton quadrangles. The stippled boundary outlines the Illinois coal field.

It is situated towards the northwest part of the Illinois coal field (fig. 33), and includes portions of four counties as follows: about 63 square miles in the southwest part of Knox, 24 square miles in southeast Warren, 24 square miles in northeast McDonough, and 340 square miles in the north part of Fulton.

The area has been mapped topographically by the State Geological Survey in co-operation with the United States Geological Survey. The name Canton Quadrangle has been given to the east half of the district from the

town of Canton, in the southeast quarter, which is situated near the center of the main coal production in this region, and the name Avon Quadrangle has been applied to the west half of this district from the town of Avon, in the northwest quarter.

In and near the borders of this district are included all of the larger coal mines of Fulton County, including 19 commercial mines, and more than 50 local mines which are worked during only a part of the year to supply local trade. Almost the entire area, except about 30 square miles near the northwest corner is probably underlain by the Rock Island (No. 1) coal which in some places is known to be 3 to 4 feet thick. Nearly three-fourths of the area is underlain by the Colchester (No. 2 or Murphysboro) coal bed which has a rather uniform thickness of about 30 inches. Approximately the eastern third of the area is also underlain by the Springfield (No. 5) coal which is between 4 and 5 feet thick and lies within easy working distance below the surface. Over somewhat more than 50 square miles in the northeast corner of the area the Herrin (No. 6) coal is also present in a thickness of nearly 5 feet.

The quality of the coals in this region is generally good, and the mining conditions in the better coal beds are usually extremely favorable. A good market for the coal output is afforded by several lines of railroad which pass through the quadrangles. The Toledo, Peoria, and Western passes near the south border of the area and affords a good outlet to the east and west. A branch of the Chicago, Burlington and Quincy passes through Canton, Brereton, Norris, and Farmington, near the east side of the district. The Minneapolis and St. Louis passes through London Mills and Farmington in the north part of the area. The West Havana branch of the Chicago, Burlington and Quincy crosses the central part, through Cuba, Ellisville, and London Mills; and the Chicago and Kansas City branch of the Chicago, Burlington and Quincy passes near the west side of the area through Bushnell, Prairie City, Avon, and St. Augustine. Besides these steam roads the Illinois Central electric road connects St. David, Canton, Norris, and Fairview in this area.

Acknowledgments

Reports on the geology of Fulton, Warren, and Knox counties were published by Worthen in 1870, in which he made the section of Pennsylvanian rocks in Fulton County[1] the type for western and central Illinois.

The annual Coal Reports for the State[2] have given important information concerning mining and mining equipment, and statistics on the coa production of this area from year to year.

[1]Worthen, A. H., Geol. Survey of Illinois, vol. IV, p. 92, 1870. See also vol. 5, p. 253, 1873, for the geology of McDonough County.

[2]Of recent years these reports have been published by the Department of Mines and Minerals. Earlier reports were issued by the State Mining Board and the Bureau of Labor Statistics.

Leverett has described some of the topographic features and published the records of a few water wells in this region.[1]

S. O. Andros[2] has described the coal-mining practice in District IV, which includes the area under consideration. The coal operators in this area very generously furnished the Survey copies of the private records of their shafts and test borings which were of great help in the preparation of the structure data included on the geologic map (Pl. I) which accompanies this paper. Appreciation of this favor is here gladly acknowledged.

Surface Relief and Drainage

The range of surface relief in the Canton and Avon quadrangles is a little more than 300 feet, although the altitude over much the greater part of the uplands is included between 640 and 760 feet above the sea. The lowest point is about three miles east of the town of Marietta, where Spoon River leaves the Avon quadrangle at an elevation of about 474 feet. The highest elevation is at the top of a low hill, about 2 miles west of Norris, which rises slightly above 780 feet.

The surface drainage of all but about 30 square miles along the east margin of the area is accomplished by Spoon River and its branches. This river is tributary to the Illinois, which it joins about 20 miles southeast of the area, opposite the city of Havana. The more important tributaries to Spoon River in this area are Cedar Creek in the northwest portion, Shaw Creek in the southwest, and Big, Littlers, Coal, and Put creeks in the east. The detailed topography of the area, including the location of timber tracts, public roads, railroads, and houses, is shown on the topographic map of the quadrangles. The relief and altitude of the surface are indicated on this map by contour lines, each of which passes through points of equal elevation above the sea. The successive contour lines are separated on the ground by a vertical interval of 20 feet.

A belt of floodplain 1¼ to 1½ miles wide borders Spoon River, and narrower areas of floodplain border the larger creeks in the region. The surface of the uplands is gently sloping, but in some places adjacent to the river and larger creeks a fairly rugged topography has been developed.

GENERAL GEOLOGY

In the study of the geology of this region an effort was made to determine the number of coal beds of commercial importance occurring in the quadrangles; the area underlain by each of these beds; the thickness and the depth below the surface of each bed at different points; and the structure of the beds, including the dips and deformations of the coals and the char-

[1]Leverett, Frank, The Illinois Glacial Lobe: U. S. Geol. Survey Mon. 38, 1899.
[2]Andros, S. O., Coal Mining Practice in District IV: Ill. Coal Mining Investigations Bull. 12, 1915.

acter of the associated strata as factors affecting the quality of the coal and the ease of mining.

The data on the coals were largely obtained from a study of surface outcrops which are frequent in many places along the larger streams. Important information was also secured from the records of coal test borings and mine shafts that have been put down in the area. Additional information was also derived from the logs of water wells in various places.

Stratigraphy

The rocks of the Avon and Canton quadrangles consist of a mantle of surficial materials, overlying more consolidated beds of indurated rocks.

SURFICIAL MATERIALS

The thickness of the surficial materials in this area varies from almost nothing to 155 feet. In 293 wells and test borings that passed through the unconsolidated deposits, the average thickness was 38 feet. These deposits are thin over the upland areas that constituted the higher lands during the late pre-glacial time, and are deep over the valleys of the early Pleistocene streams. The larger of these ancient drainage courses are followed, for considerable distances, by the present streams of the area. These pre-glacial channels were considerably deeper and broader than the present valleys, as shown by the fact that over a belt 2 to 3 miles wide bordering Spoon River and Cedar Creek the ancient channels were eroded in the Pennsylvanian strata 70 to 100 feet below their present floodplains and 1 to 2 miles wider than their present valleys.

Over the uplands the surficial materials are of Pleistocene age and consist of a bed of fine-grained silt, known as loess, 10 to 18 feet thick, underlain by pebbly clay or till of Illinoian age, which has a variable thickness of a few to 20 or more feet. Along the stream valleys where the surficial deposits are thick, they consist largely of fluvial or fine, glacio-fluvial materials. They are composed for the most part of sand and clay with an occasional bed of gravel in the lower part.[1]

INDURATED ROCKS

All of the indurated rocks exposed in the Avon and Canton quadrangles consist of nearly horizontal strata of sedimentary origin and belong to the Mississippian and Pennsylvanian systems. They outcrop in many places along the streams, and comprise sandstones, shales, thin limestones, and occasional beds of coal.

The entire section of the Pennsylvanian or "Coal Measures" strata can be studied in natural exposures in the area and the upper portion of the

[1]Savage, T. E., Relations of loess and drift in Canton quadrangle: Ill. State Geol. Survey Bull. 30, pp. 109-114, 1917.

Burlington limestone, belonging to the Mississippian, is also exposed. Below the rocks that outcrop in the area, a thickness of 1300 feet of Paleozoic strata are known from a study of the records of deep wells put down for water in this region, the deepest of which penetrate the St. Peter sandstone. A section of the rocks encountered in deep borings is shown in the following detailed records.

DETAILED WELL SECTIONS

The city of Canton obtains its water supply from a deep well put down to the St. Peter sandstone. The Parlin and Orendorff Plow Company has also drilled a well to the same horizon for their water supply. There is given below a log of the latter well, put down in 1896, as furnished by the company, with the interpretations of the several formations:

Log of well of Parlin and Orendorff Plow Company at Canton

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system—		
Pleistocene and Recent—		
Surface clay	22	...
Sand	2	24
Clay, blue	16	40
Pennsylvanian system—		
Carbondale formation—		
Shale	40	80
Coal (Springfield or No. 5)	4½	84½
Shale	15	99½
Limestone	20	119½
Shale	61	180½
Shale	15	195½
Shale	30	225½
Coal (Murphysboro or No. 2)	1½	227
Pottsville formation—		
Clay shale	6	233
Shale	15	248
Flint	5	253
Shale	35	288
Shale	7	295
Coal	1	296
Shale	12	308
Shale	50	358
Limestone (?)	17	375
Shale	23	398
Limestone (?), blue	18	416
Shale, sandy	12	428
Sandstone and conglomerate	30	458
Sandstone	7	465

Log of Parlin and Orendorff well—Concluded

	Thickness *Feet*	Depth *Feet*
Mississippian system—		
Burlington formation—		
Limestone, white	100	565
Kinderhook shale—		
Shale, gray, calcareous, about	125	690
Devonian system—		
Upper Devonian shale—		
Shale, dark, with *Sporangites,* about	101	791
Wapsipinicon limestone—		
Limestone, gray	62	853
Silurian system—		
Niagaran limestone—		
Limestone, magnesian	127	980
(Horizon of the Hoing sand)		
Ordovician system—		
Maquoketa shale—		
Shale and limestone	175	1155
Galena-Platteville limestone—		
Limestone	186	1341
Sandstone (?) (probably dolomite)	5	1346
Limestone	10	1356
Sandstone and limestone mixed	20	1376
Limestone	69	1445
St. Peter sandstone—		
Sandstone, white	282	1727

The city well at Cuba passed through a succession of strata similar to those described in the above record, and reached the St. Peter sandstone at about the same depth, as shown below:

Log of deep well for city water supply at Cuba, Illinois[1]
Elevation of curb, 677 feet

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system—		
Pleistocene and Recent—		
Soil and clay	34	34
Pennsylvanian system—		
Carbondale and Pottsville formations—		
Shale, sandy	68	102
Sandstone	4	106
Coal (Springfield or No. 5 bed)	5	111
Shale and sandstone	144	255
Limestone (?), hard, black	5	260
Shale, gray and dark	50	310
Limestone (?), white	25	335
Shale	95	430

[1]Compiled in part from a record furnished by the City Clerk, and in part from a study of samples of drilling sent to the Survey by O. Klutz.

Log of Cuba City well—Concluded

	Thickness *Feet*	Depth *Feet*
Mississippian system—		
Burlington limestone—		
Limestone, white to gray, largely replaced by chert	95	525
Limestone, dolomitic, white to light gray, with some chert	105	630
Kinderhook shale—		
Shale, gray, calcareous	130	760
Devonian system—		
Upper Devonian (Sweetland Creek) shale—		
Shale, gray to dark, with spores of *Sporangites huronense*	55	815
(Horizon of Wapsipinicon-Devonian limestone, but if present, it was not distinguished from the underlying Silurian)		
Silurian system—		
Niagaran limestone (possibly in part Devonian)—		
Dolomite, gray to brown	70	945
Dolomite, gray, with a very little hard dark shale	95	1040
Ordovician system—		
Maquoketa shale—		
Shale, dark gray to brown	45	1085
Shale, light gray, slightly dolomitic	80	1165
Galena-Platteville limestone—		
Dolomite, dark gray, with some pyrite	45	1210
Dolomite, gray to tan color	360	1570
St. Peter sandstone—		
Sandstone, white, of clear rounded quartz grains	190	1760

The following is the log of a well drilled a few miles south of the Avon quadrangle, near the town of New Philadelphia. All but the upper 238 feet of this record was compiled from a study of samples that were saved from every bailer as the well was put down. The upper part was taken from the driller's record.

Log of well drilled near New Philadelphia

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system—		
Pleistocene and Recent—		
Soil and yellow clay	17	17
Sand, soft	2	19
Clay, blue	39	58
Quicksand and fine gravel (gas at 58 feet)	4	62
Gravel, with water and gas	10	72
Pennsylvanian system—		
Pottsville formation—		
Limestone (?)	14	86
Shale, blue	69	155
Mississippian system—		
Burlington limestone—		
Limestone, white to light gray (with water)	190	345

Log of well drilled near New Philadelphia—Concluded

	Thickness *Feet*	Depth *Feet*
Kinderhook shale—		
Shale, light gray to bluish	85	430
Devonian system—		
Upper Devonian (Sweetland Creek) shale—		
Shale, dark and light	155	585
Wapsipinicon limestone—		
Limestone, light gray; slight showing of oil at 610 and 635 feet	56	641
Silurian system—		
Limestone, gray, magnesian	10	651
(Horizon of Hoing sand)		
Ordovician system—		
Maquoketa shale—		
Shale, bluish gray	160	811
Shale, gray, somewhat sandy	20	831
Galena limestone—		
Dolomite, yellowish gray	89	920

ROCKS EXPOSED

MISSISSIPPIAN SYSTEM

BURLINGTON LIMESTONE

The oldest rocks exposed in the Avon and Canton quadrangles belong to the Burlington formation of the Osage group. They outcrop in a few places along Cedar Creek and its branches in the Avon quadrangle, exposing a thickness of 10 to 13 feet.

In sec. 31, T. 9 N., R. 1 E., the following section is exposed in the west bank of Cedar Creek.

Section of strata exposed in sec. 31, T. 9 N., R. 1 E.

	Thickness *Feet*
Quaternary system—	
Pleistocene and Recent—	
8. Loess	5
7. Till, pebbly, reddish brown	4
Pennsylvanian system—	
Pottsville formation—	
6. Sandstone, gray	7
5. Shale, bluish, or shaly sandstone	4
4. Coal	1½
3. Shale, dark and gray	14
2. Sandstone, gray; in places absent when the chert is highest	6
Mississippian system—	
Burlington chert—	
1. Chert, in layers 3 to 7 inches thick	11
	52½

In this place the uneven contact of the Burlington and Pottsville formations is exposed for several rods, at an altitude of 571 to 578 feet. The chert masses in the lowest member of the above section contained the following fossils:

Fossils from Burlington chert exposed in sec. 31, T. 9 N., R. 1 E.

Granatocrinus cf. norwoodi Owen and Shumard
Fenestella sp.
Hemitrypa sp.
Productus burlingtonensis Hall
Productus viminalis White
Spirifer incertus Hall
Spirifer grimesi Hall
Spiriferella latior Weller
Syringothyris sp.
Athyris lamellosa (Leveille)
Orthonychia sp.
Platyceras sp.
Myalina sp.

The contact of the Burlington strata with the Pottsville is also well exposed in the east bank of Cedar Creek about a mile farther north, and again in the bank of a tributary of Cedar Creek, in sec. 30, T. 9 N., R. 1 E., where the following section was made:

Section of strata exposed near the middle of the east half of sec. 30, T. 9 N., R. 1 E.

	Feet
Quaternary system (Pleistocene and Recent)—	
Loess, gray to yellow	3
Till, brown, pebbly	5
Pennsylvanian system (Pottsville formation)—	
Shale, dark gray	6
Mississippian system (Burlington limestone)—	
Chert, gray; in layers 3 to 9 inches thick	5
Limestone, light gray, crinoidal, in layers 3 to 12 inches thick	8

The top of the Burlington limestone at this place has an altitude of about 603 feet, and the strata afforded fossils similar to those given in the former list.

PENNSYLVANIAN SYSTEM

The Pennsylvanian strata in this region rest in irregular unconformity upon the Burlington limestone of the Mississippian system, from which they are separated by a sedimentary break of very considerable length. In some places the lower 30 or 40 feet of Pennsylvanian rocks consist chiefly of sandstone, while in other places little or no sandstone occurs in the basal

portion. In the middle and upper parts of the Pennsylvanian section, shale sediments far exceed the sandstones, and occasional bands of limestone and beds of coal are also present. Worthen made the section of Pennsylvanian strata exposed in Fulton County the type or standard section for the correlation of the "Coal Measures" strata in the central and western parts of the State. He found exposed in this region seven coal beds, four of which have been mined to a greater or less extent. He applied consecutive numbers to the more important of these coal beds, beginning with No. 1 at the bottom. The coals he numbered 4 and 5 respectively in this region are now known to be the same bed; the early misinterpretation was due to confusion arising from the much smaller interval between coals No. 5 and No. 6 in the vicinity of Cuba than farther east in Fulton County, and also from the fact that owing to local deformation the elevation of No. 5 coal, where it is exposed on opposite sides of a creek north of Cuba, varies nearly 30 feet.

CORRELATION

From a study of the fossil plants, David White has concluded that the Pottsville, Allegheny, and Conemaugh formations of the Appalachian region are represented in Illinois. The equivalent of the Pottsville formation of the eastern states includes the strata from the base of the Pennsylvanian up to the base of the Colchester (No. 2, or Murphysboro) coal bed, and these strata will be referred to the Pottsville formation. On account of the uncertainty of the plane of division between the strata representing respectively the Allegheny and Conemaugh formations in Illinois, local formation names, the Carbondale and the McLeansboro, have been applied to the Pennsylvanian strata above the Pottsville in this region, the top of the Herrin or No. 6 coal being made the division between these formations.

POTTSVILLE FORMATION

Character and thickness.—In the southern part of the state the Pottsville formation consists dominantly of sandstone, and has a thickness of 500 to 700 or more feet, but in the Avon and Canton quadrangles the sandstone sediments are subordinate to shale in this formation and the thickness does not exceed 125 feet.

Strata between the base of the Pottsville and the Rock Island[1] *(No. 1) coal.*—Pottsville strata occurring below No. 1 coal in this region outcrop in several places in the Avon quadrangle as shown on the map (Plate I). They are exposed in an abandoned quarry on the north side of a tributary of Spoon River, a few rods west of Marietta Station, in the NW. ¼ sec. 22, T. 6 N., R. 1 E. (fig. 34). The succession of strata at this place is described in the following section:

[1]The manuscript for the report on the Avon and Canton quadrangles was prepared before the field study on the Edgington and Milan quadrangles was made. As a result of the field study of the latter area it seems probable that some name other than "Rock Island" should be applied to the No. 1 coal bed.

Section of rocks in an abandoned quarry near Marietta Station

		Ft.	*In.*
13.	Shale, gray	6	..
12.	Sandstone, gray to brown	10	..
11.	Shale, gray, having a 3 to 6-inch concretionary layer 2½ feet from the bottom	7	..
10.	Coal	1	..
9.	Clay shale, gray, becoming sandy in the lower part and containing numerous crystals of selenite	2	6
8.	Limestone, hard, dark colored, consisting largely of septarian nodules and containing *Lophophyllum profundum, Productus semireticulatus,* and *Composita argentea*	1	8
7.	Clay shale, gray	2	6
6.	Shale, black bituminous	..	2
5.	Clay shale, gray, with selenite crystals	5	..
4.	Coal band, about	..	4
3.	Shale, dark gray	3	6
2.	Shale, black, fissile	9	..
1.	Sandstone, gray to brown, in thick layers, the top deeply stained and firmly cemented with iron	12	..

FIG. 34. Photograph showing Pottsville strata below No. 1 coal, exposed in an old quarry a few rods west of Marietta Station.

A boring at Leaman station, half a mile east of the exposure described above, passed through 35 feet of shale and sandstone, and 60 feet of hard limestone, the latter belonging to the Mississippian system. The top of this boring was about 20 feet below the level of the Rock Island (No. 1) coal bed which outcrops in the north bank of the stream at that place. This would indicate a thickness of about 55 feet of Pottsville strata below No. 1 coal in this region.

Farther north along the wagon road up the hill between Marietta station and the town, the following layers are exposed above the level of the top of the preceding section:

Section in the hill north of Marietta station

	Ft.	In.
5. Sandstone, yellow to brown	7	..
4. Shale, gray	5	..
3. Limestone, dark, fossiliferous, with a 2-inch band of cone-in-cone structure at the top	7	..
2. Shale, dark	..	6
1. Coal (Rock Island or No. 1)	2	3

Sandstone and shale of early Pottsville age outcrop to a height of 16 to 20 feet in a number of places along the banks of Cedar Creek and its branches in sections 22, 23, 26 and 27, T. 9 N., R. 1 W., near the northwest corner of the Avon quadrangle. In the south bank of the creek in the NE. ¼ sec. 26 of this township the following succession of strata is exposed:

Section of rocks exposed in the N.E. ¼ sec. 26, T. 9 N., R. 1 W.

	Feet
4. Sandstone, gray to yellow, massive and irregularly bedded	11
3. Coal	1
2. Shale, clayey	3½
1. Coal	1½

Two thin coals separated by 3 to 6 feet of shale usually occur 20 to 25 feet below the Rock Island (No. 1) coal bed. A few feet of shale frequently lie between the upper coal and the overlying sandstone, and 10 to 14 feet of dark shale usually underlies the lower coal bed of the last section. About a quarter of a mile farther down this stream on the same side of the valley, strata belonging above the top of the section last given are well exposed.

Section of strata near the middle of the east side of sec. 26, T. 9 N., R. 1 W.

	Feet
4. Limestone (cap rock of No. 1 coal), dark, shaly, fossiliferous	9
3. Coal (Rock Island or No. 1 bed)	3¼
2. Shale, clayey	1
1. Sandstone, the top containing very numerous rootlets of *Stigmaria*	5

In this region *Stigmaria* with casts of numerous rootlets attached are generally abundant in the upper part of the sandstone a few feet below the

Rock Island coal, as in the east bank of Swan Creek in the NE. ¼ sec. 23, T. 8 N., R. 1 W., and near the middle of the S. ½ sec. 10, T. 6 N., R. 1 E., and at several other places. In sections 30 and 31, T. 9 N., R. 1 E., less than 2 miles east of the outcrop last described no sandstone occurs below the thin coal beds in the lower part of the Pottsville formation, as may be seen in the sections on a preceding page showing the contact of the Burlington limestone and the Pottsville formation. It is probable that the surface of the Mississippian limestone on which the basal Pottsville sediments were laid down in this region had a relief of at least 40 feet, and probably more, so that the sandstones that occur in the basal part of the Pottsville were deposited in the depressions, and the higher portions of the Mississippian surface were not submerged by the Pottsville sea until after the lower sandstones were laid down.

Rock Island (No. 1) coal and associated strata.—Worthen made the coal bed outcropping in the west bank of Spoon River near the village of Seville, the type of No. 1 coal for this part of Illinois. This coal, which is probably equivalent to the Rock Island (No. 1) coal, occurs about 25 feet above the middle of the Pottsville formation. It is well exposed along the Toledo, Peoria, and Western Railroad, one and one-half miles below Seville station, as shown in figure 35 and described below:

Section along the Toledo, Peoria and Western R. R.,
1¼ miles below Seville station

	Feet
5. Shale, gray	10
4. Limestone, nodular, shaly, fossiliferous, in layers 1 to 2 inches thick	5
3. Shale, black	2
2. Coal, Rock Island (No. 1) bed	3¼
1. Shale, gray, clayey	2½

Along Spoon River, half a mile below Seville station, about 6 feet of sandy shale is exposed below the Rock Island coal, and is underlain by 12 feet of sandstone and sandy shale, beneath which is a thickness of 15 feet of massive sandstone extending down to the water in the river.

The Rock Island coal is exposed at a number of places in the Avon quadrangle and ranges in thickness from 1 to 4½ feet. Its development is somewhat irregular, and it is absent at a few places where its horizon is exposed. It is mined on a commercial scale at Ellisville station and intermittently near Ellisville in the vicinity of Babylon, at London Mills near the center of the east line of sec. 10, T. 7 N., R. 1 E., and in the NE. ¼ of the SW. ¼ sec. 10, T. 8 N., R. 1 E. This coal is usually overlain by a dark, somewhat impure limestone (fig. 35) that varies in thickness from 5 to 20 feet, which may be separated from the coal by ½ to 3 feet of dark shale. Besides the localities in the vicinity of Seville, the Rock Island coal and its

FIG. 35. Photograph of an outcrop of Rock Island (No. 1) coal and the overlying limestone in the west bank of Spoon River below Seville.

limestone cap rock are well exposed in the bed of a small tributary to Spoon River near the middle of the west side of sec. 13, a short distance below the wagon bridge at Babylon. They are well exposed at a number of places along Aylesworth branch and its tributaries, near the middle of the east side of sec. 10, and in the S. ½ of sec. 11, T. 7 N., R. 1 E.

The cap rock of the Rock Island coal outcrops in the bed of Spoon River just above the wagon bridge at Ellisville. It is also exposed to a height of 8 feet in both banks of Put Creek below the wagon bridge, near the middle of sec. 4, T. 6 N., R. 2 E. Corresponding strata are also well exposed in the east bank of Cedar Creek in the SE. ¼ sec. 10, T. 8 N., R. 1 E., where the following section was made:

Section of Rock Island (No. 1) coal and cap rock in the SE. ¼ sec. 10, T. 8 N., R. 1 E.

	Feet
3. Limestone, dark, shaly hard, fossiliferous	10
2. Shale, dark	½
1. Coal, Rock Island (No. 1) bed	4

Strata corresponding to the above outcrop in the north bank of Cedar Creek near the west side of the same section, and are also exposed for about 40 rods in the north bank of Cedar Creek, as in the NE. ¼ sec. 26, T. 9 N., R. 1 W., as shown below:

Section of strata exposed in the NE. ¼ sec. 26, T. 9 N., R. 1 W.

		Feet
5.	Limestone, dark, shaly, fossiliferous	8
4.	Shale, dark	½
3.	Coal, Rock Island (No. 1) bed	3
2.	Shale, clayey	1
1.	Sandstone, gray micaceous, with numerous *Stigmaria* and rootlets at top	5

The strata at this place are inclined towards the east a little greater than the fall of the stream. In the south bank of the creek, near the east end of this exposure, the sandstone overlying the cap rock above the Rock Island coal has been quarried to a height of 10 feet and is succeeded by 6 feet of shale. The exposure of the Rock Island coal and limestone cap rock described in the above section terminates at the west by a small fault which has brought up beds belonging beneath the coal so that a ledge of rather massive sandstone, 6 to 10 feet thick, occurs at the level of the limestone on the opposite side of a small ravine tributary to the creek on the north.

In some places the Rock Island coal and its limestone cap rock are both absent, as in the exposure in the east bank of Swan Creek, in the NE. ¼ sec. 23, T. 8 N., R. 1 W.; in the south bank of Shaw Creek, in the SE. ¼ sec. 10, T. 6 N., R. 1 E.; and at a few other places in the Avon quadrangle.

The limestone above the Rock Island coal in places contains many fossils, among which are the following species:

Fossils from the dark limestone above the Rock Island (No. 1) coal

Fossils	Near Marietta	Near Seville	Near Ellisville
Lophophyllum profundum Edwards and Haime	x	x	x
Euphachyrinus crassus Meek and Worthen	....	x	....
Fistulipora sp	....	x	....
Fenestella delicatula Ulrich	....	x	....
Fenestella mimica Ulrich	....	x	....
Fenestella perminuta Ulrich	....	x	....
Fenestella wortheni Ulrich	....	x	....
Polypora whitei Ulrich	....	x	....
Thamniscus sevillensis Ulrich	....	x	....
Pinnatopora bellula Ulrich	....	x	....
Septopora delicatula Ulrich	....	x	....
Diploporaria biserialis Ulrich	....	x	....
Rhombopora cf. multipora Foreste	....	x	....
Chainodictyon laxum var. minor Ulrich	....	x	....
Orbiculoidea cf. manhattanensis Meek and Hayden	....	x	....
Orbiculoidea missouriensis Shumard	....	....	x
Derbya crassa Meek and Hayden	x	x	x
Derbya cf. robusta Hall	....	x	....

Fossils from the dark limestone above the Rock Island (No. 1) coal—Concluded

Fossils	Near Marietta	Near Seville	Near Ellisville
Chonetes mesolobus Norwood and Pratten	x	x	x
Productus cora D'Orbigny	....	x	....
Productus nanus Meek and Worthen	x	x	....
Productus semireticulatus Martin	x	x	x
Marginifera muricata Norwood and Pratten	x	x	x
Marginifera splendens Norwood and Pratten	....	x	x
Pugnax uta Marcou	x	....	....
Dielasma bovidens Morton	....	x	....
Spirifer cameratus Morton	x	x	x
Spirifer rockymontana Meek	....	x	....
Spiriferina kentuckyensis Shumard	x	x	....
Squamularia perplexa McChesney	x	x	....
Ambocoelia planiconvexa Shumard	x	x	....
Hustedia mormoni Marcou	....	x	....
Composita argentea Shepard	x	x	x
Solenomya soleniformis Cox	....	x	....
Cardiomorpha missouriensis Shumard	x	....	....
Yoldia knoxensis McChesney	x	....	....
Yoldia rushensis McChesney	x	....	....
Schizodus sp	x	....	....
Aviculopecten sp	x	....	x
Entolium aviculatum Swallow	x	x	....
Allorisma cuneatum Swallow	....	x	....
Astartella concentrica McChesney	x	....	....
Pleurotomaria speciosa Meek and Worthen	x	....	....
Phanerotrema grayvillensis Norwood and Pratten	x	x	....
Euphemus carbonarius Cox	x	....	....
Schizostoma catilloides Conrad	x	....	....
Meekospira inornata (?) Meek and Worthen	x	....	....
Meekospira peracuta Meek and Worthen	x	....	....
Soleniscus brevis White	x	....	....
Soleniscus truncata (?)	....	x	....
Sphaerodoma ponderosa Swallow	x	....	....
Platyceras cf. parvum Swallow	x	x	....
Orthoceras rushense McChesney	x	....	....

Pottsville strata above the cap rock of the Rock Island (No. 1) coal.—The limestone above the Rock Island coal is usually succeeded by 10 to 13 feet of sandstone above which shale predominates up to the Colchester (No. 2) coal bed. The sandstone is well exposed in the north bank of Cedar Creek near the middle of the west side of sec. 10, and in the south bank of the creek in the SE. ¼ sec. 9, T. 8 N., R. 1 E. At the latter place the following strata are exposed:

Section of strata exposed in the south bank of Cedar Creek in SE. ¼ sec. 9, T. 8 N., R. 1 E.

	Feet
5. Shale, dark	4
4. Coal	1
3. Shale, hard black, laminated	2½
2. Shale, dark	2½
1. Sandstone, gray, micaceous	13

An almost complete section of the strata between the limestone above the Rock Island coal and the Colchester (No. 2) bed, is passed over in the wagon road going up the hill from Aylesworth branch in the NW. ¼ sec. 14, T. 7 N., R. 1 E., as shown below:

Section of strata exposed along the wagon road in the NW. ¼ sec. 14, T. 7 N., R. 1 E.

	Feet
13. Shale, gray	15
12. Shale, black, bituminous	⅔
11. Shale, gray	8
10. Coal	1
9. Shale, gray	6
8. Coal	½
7. Shale, gray	9
6. Limestone, nodular septarian, with very irregular surfaces	⅔
5. Shale, gray	3
4. Shale, black laminated	2
3. Shale, gray to dark, hard	7
2. Coal	1 to 2
1. Sandstone, gray, and sandy shale	12

The band of very rough septarian nodular limestone, ½ to 1½ feet thick, is persistent in this region 25 to 35 feet above the Rock Island coal, and only 3 to 9 feet below another thin bed. Strata similar to those described in the foregoing section outcrop along the banks of another tributary to Aylesworth Branch along the south side of sec. 10, and in the SW. ¼ sec. 11, T. 7 N., R. 1 E. The band of nodular limestone and overlying strata are also exposed along the tributaries of Spoon River in the SE. ¼ sec. 29, and in the banks of Turkey Creek and its branches in sec. 27, T. 7 N., R. 2 E., as shown in the section given below:

Section of strata exposed in east bank of Turkey Creek, near the middle of sec. 27, T. 7 N., R. 2 E.

	Feet
5. Sandstone, gray, micaceous	3
4. Shale, gray	11
3. Coal	1
2. Shale, gray	4
1. Limestone, nodular, septarian, with very irregular surfaces	1

Strata equivalent to the above are exposed along Shoal Creek in sec. 35, T. 7 N., R. 1 E., and secs. 1 and 12, T. 6 N., R. 1 E. The following section is exposed in the west bank of this creek near the NE. corner of sec. 12.

Section of rocks exposed near the northeast corner of sec. 12, T. 6 N., R. 1 E.

		Feet
5.	Shale, gray	6
4.	Coal	1
3.	Shale, gray	5½
2.	Limestone, irregular, septarian, nodular	1
1.	Shale, gray	5

Farther south along the lower course of Shaw Creek and its tributaries in secs. 9, 10, 11, 13, and 14, T. 6 N., R. 1 E., there are numerous outcrops of strata belonging in the interval between No. 2 coal and the limestone above the Rock Island (No. 1) coal as shown in the following representative section given below:

Section of strata exposed in the NW. ¼ sec. 13, T. 6 N., R. 1 E.

		Feet
11.	Shale, black, laminated, with a 6-inch band of fossiliferous concretionary limestone	2½
10.	Shale, gray	12
9.	Coal (Murphysboro or No. 2)	2¼
8.	Shale, gray to blue	17
7.	Sandstone, gray, micaceous	3
6.	Shale, gray	5
5.	Shale, sandy, laminated	1
4.	Shale, gray	2½
3.	Coal	1
2.	Shale, gray	4
1.	Limestone, septarian, nodular and irregular	1

In the north half of the Avon quadrangle, Pottsville strata above the limestone overlying the Rock Island coal outcrop in several places along Cedar Creek and Spoon River and their tributaries, a representative section of which is well exposed in the west bank of Cedar Creek, near the middle of the west side of sec. 1, T. 8 N., R. 1 E., where the following section was made:

Section of strata exposed in the west bank of Cedar Creek in sec. 1, T. 8 N., R. 1 E.

		Feet
11.	Coal (Colchester or No. 2)	1¾
10.	Shale, somewhat concealed	25
9.	Sandstone, gray, in thick and thin layers	3 to 8
8.	Sandstone, gray, in thin laminae alternating with dark shale	6
7.	Sandstone, gray, massive, lenticular	2 to 8
6.	Coal	½
5.	Shale, gray, clayey	3½
4.	Shale, black, laminated	3
3.	Coal, shaly	1
2.	Shale, gray to dark	6
1.	Sandstone, gray, micaceous	5

Strata corresponding to some part of the above section outcrop in the banks of a number of the streams tributary to Cedar Creek on the north between the place where the last section was made and London Mills. They are well exposed in the east bank of Cedar Creek, near the middle of sec. 5, T. 8 N., R. 2 E., and they outcrop in the west bank of Spoon River, in the SW. ¼ sec. 27, T. 9 N., R. 2 E., as shown in figure 36 and described in the following section:

FIG. 36. View of the strata below No. 2 coal, exposed in the west bank of Spoon River in the SW. ¼ sec. 27, T. 9 N., R. 2 E.

Section of strata exposed in the west bank of Spoon River in sec. 27, T. 9 N., R. 2 E.

	Feet
5. Sandstone, gray, micaceous	9
4. Coal	1
3. Shale, gray and dark, with bands of sandstone	28
2. Shale, black, laminated, with septarian nodules underlying a thin coal near the top	14
1. Sandstone, gray, in thin layers	9

Near the heads of the small branches that join the river in the southwest quarter of this section, No. 2 coal has been stripped at a number of places at an altitude of about 584 feet, less than 10 feet higher than the top

of the section given above. In the northwest quarter of the Avon quadrangle, strata belonging near the top of the Pottsville formation are well exposed in a number of places between a place a short distance east of the middle of the west side of sec. 22, T. 8 N., R. 1 W., and the junction of this stream with Swan Creek, and in the banks of smaller tributaries of Swan Creek, in sec. 23 of the same township. A section of the strata exposed in the SW. ¼ sec. 14 of this township is given below:

Section of strata exposed in the SW. ¼ sec. 14, T. 8 N., R. 1 W.

		Feet
6.	Shale, gray	4½
5.	Coal	⅔
4.	Shale, gray to dark	12
3.	Coal	1
2.	Shale, gray and dark	20
1.	Sandstone, gray	7

Strata corresponding to some part of those of the above section also outcrop in many places along the streams in secs. 19, 30, and 31, T. 9 N., R. 1 E.

CARBONDALE FORMATION

The Carbondale formation in Illinois includes all of the Pennsylvanian strata lying between the base of the Murphysboro (Colchester or No. 2) coal and the top of the Herrin (No. 6) bed. The name is taken from the town of Carbondale, in Jackson County, Illinois, in the vicinity of which the rocks of this formation are well exposed. The Carbondale strata in the Avon and Canton quadrangles range in thickness from 120 to 175 feet, and consist of shale and sandstone with thin bands of limestone and a few beds of coal.

Strata between the Murphysboro (No. 2) coal and the septarian nodular limestone.—The No. 2 coal is known locally as the 30-inch bed, and its thickness is remarkably uniform, averaging about 2½ feet over all of this region. In many places in the Avon quadrangle this coal is worked by stripping and in drift mines, as in the vicinity of London Mills, Avon, and Marietta.

The Colchester (No. 2) coal is everywhere immediately overlain by a bed of rather soft, bluish-gray shale, which makes a poor roof. The thickness of this shale is 9 to 14 feet in the northern and western parts of the region, but it thickens toward the south. It is followed above by a black laminated shale, 3 to 6 feet thick, near the middle part of which in most places there occurs a band of very fossiliferous septarian, nodular limestone, ½ to 1 foot thick, the uppermost 2 inches of which shows cone-in-cone structure. This easily recognized succession of strata is exposed in many places in the Avon quadrangle, and at a few points near the west side of the Canton. In the northwest quarter of the former quadrangle these strata outcrop in the south bank of Swan Creek and near the heads of the tribu-

taries on the south in the south half of section 23, and in section 24, T. 8 N., R. 1 W. They are also exposed in the banks of the creek north of the wagon road in the NW. ¼ section 22 of the same township, where the following section was made:

Section of strata exposed in the NW. ¼ sec. 22, T. 8 N., R. 1 W.

	Feet
6. Shale, gray	5
5. Limestone, dark, septarian, nodular, fossiliferous, with a band of cone-in-cone structure at the top	1
4. Shale, gray to dark	3½
3. Shale, black, laminated, with pyritic concretions	2
2. Shale, gray	9½
1. Coal (Colchester or No. 2)	2

In the southwest quarter of the Avon quadrangle, the No. 2 coal has been mined by drifts at several places along the streams in sections 7, 8, 9, 15, 16, 17, and 18, T. 6 N., R. 1 E. At the middle of the north half of section 18 of this township the following section was made where the strata are exposed dipping gently toward the north.

Section of strata exposed near the middle of the N. ½ sec. 18, T. 6 N., R. 1 E.

	Feet
4. Shale, black, laminated, with a band of septarian, nodular limestone near the middle	2½
3. Shale, gray	12½
2. Coal (Colchester or No. 2) bed	2¼
1. Shale, gray	9

The horizon of No. 3 coal, as described by Worthen, belongs immediately below the black laminated shale containing the band of septarian nodular limestone, but no coal occurs at this horizon in any portion of the Avon and Canton quadrangles. The coal outcrops cited by Worthen near Marietta, and in the bed of Coal Creek 3 miles northwest of Fairview, are both the Colchester (No. 2) coal of this region. An outcrop in the banks of a ravine in the NW. ¼ sec. 18, T. 6 N., R. 2 E., shows the following section:

Section of strata exposed in the banks of a ravine in sec. 18, T. 6 N., R. 2 E.

	Feet
9. Shale, gray	7
8. Limestone, concretionary	⅔
7. Shale, gray	3½
6. Shale, black, laminated, with an 8-inch band of septarian nodular limestone in the middle part	2½
5. Shale, gray	12½
4. Coal (Colchester or No. 2)	2¼
3. Shale, gray	4
2. Sandstone, gray, micaceous, formerly quarried for local use	5
1. Shale, and shaly sandstone	6

Strata similar to those described in the last section are exposed in the banks of the tributaries to Spoon River on the west in sections 1, 12 and 13, T. 6 N., R. 1 E.; and also in the banks of Lost Grove Creek in the SE. ¼ sec. 27, and the SE. ¼ sec. 22, T. 7 N., R. 2 E. In the northeast quarter of the Avon quadrangle strata representing the same succession are exposed in the banks of a tributary of Coal Creek in the SE. ¼ sec. 22, T. 8 N., R. 2 E., where the No. 2 coal has been stripped at an altitude of about 566 feet.

Section of strata exposed in sec. 22, T. 8 N., R. 2 E.

		Feet
10.	Shale, dark, fissile	4
9.	Band of shaly pyritic limestone, containing the fossils, *Derbya crassa, Chonetes mesolobus, Productus cora, Marginifera muricata, Pugnax uta, Ambocoelia planiconvexa, Composita argentea, Astartella vera, Yoldia* sp., *Bellerophon percarinatus, Schizostoma catilloides,* and *Orthoceras rushense*	⅔
8.	Shale, dark	5
7.	Shale, black, laminated, with a band of septarian nodular limestone near the middle	3½
6.	Shale, gray and dark	9
5.	Coal (Colchester or No. 2)	2½
4.	Shale, clayey, bluish-gray	3½
3.	Sandstone, gray	7½
2.	Shale, sandy with concretions	3½
1.	Shale, black, laminated	1½

The Colchester coal (No. 2) has also been mined by drifts in the banks of a creek northwest of London Mills, in the SW. ¼ sec. 28, and in the SE. ¼ sec. 29, T. 9 N., R. 2 E., at an altitude of about 579 feet. This coal has been stripped in a few places near the heads of the streams in the southwest quarter sec. 27, in the same township at an altitude of 581 feet. In every place where the septarian nodular limestone was seen, it contained numerous fossils among which pelecypods were abundant. The fossils obtained from this layer are listed below:

Fossils from the septarian nodular limestone

Fossils	Near Middle sec. 12, T. 6 N., R. 2 E.	NW. ¼ sec. 4, T. 5 N., R. 3 E.	NW. ¼ sec. 35, T. 6 N., R. 3 E.
Lophophyllum profundum Edwards and Haime	x	x	....
Lingula sp	x	....	....
Orbiculoidea cf. missouriensis Shumard	....	....	x
Derbya crassa Meek and Hayden	x	x	x
Chonetes messolobus Norwood and Pratten	x	x	x
Productus cora D'Orbigny	x	x	x
Productus costatus Sowerby	....	x	....
Marginifera muricata Norwood and Pratten	x	x	x
Pugnax uta Marcou	x	x	x
Spirifer cameratus Morton	x	x	....
Spiriferina kentuckyensis Shumard	....	x	x
Squamularia perplexa McChesney	x	....	x
Ambocoelia planiconvexa Shumard	x	....	x
Composita argentea Shepard	x	x	x
Phanerotrema grayvillensis Norwood and Pratten	x	x	....
Worthenia tabulata Conrad	....	x	....
Trepospira illinoisensis Worthen	x	....	....
Euphemus carbonarius Cox	x	....	....
Petallostium montfortianum Norwood and Pratten	x	x	x
Naticopsis altonensis McChesney	?	....	x
Soleniscus brevis White	x	x	....
Soleniscus altonensis Worthen	x	....	....
Soleniscus cf. worthenanus Miller	x	....	....
Sphaerodoma cf. medialis Meek and Worthen	....	....	x
Platyceras parvus Swallow	x	....	....
Sphaerodoma pondeross Swallow	x	x	x
Solenomya trapezoides Beede	x	....	?
Clinopistha radiata var. laevis Meek and Worthen	x	....	....
Cardiomorpha missouriensis Shumard	x	....	....
Nuculopsis ventricosa Hall	x	x	....
Yoldia rushensis McChesney	x	....	x
Pseudomonotis sp	x	....	....
Myalina perattenuata Meek and Hayden	x	....	x
Euchondria neglecta Geinitz	x	....	....
Deltopecten occidentalis Shumard	x	....	....
Pleurophorus immaturus Herrick	....	....	x
Astartella concentrica McChesney	....	x	....
Orthoceras rushense McChesney	x	....	....
Metacoceras cf. sangamonensis Meek and Worthen	x	....	....

The black shale and septarian nodular limestone overlying the gray shale above No. 2 coal outcrop in several places near the west side of the Canton quadrangle. The following section was made of the rocks exposed in the banks of a tributary to Put Creek, near the center of sec. 12, T. 6 N., R. 2 E.

Section of strata exposed in sec. 12, T. 6 N., R. 2. E.

		Feet
11.	Shale, blue, the lower part containing 1 to 2-inch bands of clay-iron stone, one to two feet apart	6
10.	Shale, blue to black, with calcareous fossiliferous nodular bands 18 to 24 inches apart	4
9.	Shale, black	3
8.	Layer of very fossiliferous, septarian, nodular limestone, with a 2-inch band of cone-in-cone at the top	⅔
7.	Shale, black laminated, with many "niggerheads" ½ to 4 feet in diameter in the lower part	4
6.	Shale, bluish-gray, clayey	3
5.	Shale, blue to gray	6
4.	Coal (Colchester or No. 2 bed)	2⅓
3.	Under clay, bluish-gray	3
2.	Sandstone, yellowish-gray, in layers respectively 22, 23, and 8 inches thick	4⅓
1.	Shale, gray	6

Strata belonging to the same horizon as above, outcrop in an exposure in the NE. ¼ of sec. 34, T. 8 N., R. 2 E., as shown below:

Section of strata exposed in sec. 34, T. 8 N., R. 2 E.

		Feet
6.	Shale, gray	25
5.	Shale, bluish, the upper part with 1-inch iron-stone bands one to one and one-half feet apart	9
4.	Layer of septarian, nodular, fossiliferous limestone	½
3.	Shale, black laminated with pyrite concretions or niggerheads	3
2.	Shale, gray	9
1.	Coal (Colchester or No. 2)	2½

Corresponding strata are also exposed in the SW. ¼ of sec. 7, T. 6 N., R. 3 E.; near the middle of the N. ½ of sec. 14, and in the SE. ¼ of sec. 23, T. 6 N., R. 2 E.; and in the NE. ¼ of sec. 34, T. 8 N., R. 2 E. At these places the interval between the coal and the septarian limestone band is 9 to 15 feet, but a few miles south of the quadrangle, in the NW. ¼ of sec. 35, T. 6 N., R. 3 E., the interval between these strata is 31 feet, as shown in the following section:

Section along a tributary of Big Creek in the NW. ¼ sec. 35, T. 6 N., R. 3 E.

		Feet
8.	Sandstone and sandy shale	15
7.	Shale, dark, fissile, with 1-inch bands of iron stone 1 to 3 feet apart	5
6.	Shale, dark gray, with occasional 1-inch bands of iron stone nodules	6
5.	Layers of septarian nodular fossiliferous limestone, with cone-in-cone at top	½
4.	Shale, gray calcareous with segments of crinoid columns	½
3.	Limestone band, crinoidal	½
2.	Shale, gray	30
1.	Coal (Colchester or No. 2)	2½

A few miles southwest of the exposure last described a similar thickness of gray shale overlies the Colchester coal in the NW. ¼ sec. 4, T. 5 N., R. 3 E., as shown in figure 37. Above the septarian limestone layer at this

FIG. 37. View of No. 2 coal and the overlying shale exposed between Lewiston and Cuba.

place are several feet of shale which is followed by 8 or 10 feet of sandstone In the Canton quadrangle a bed of gray shale everywhere lies above the septarian limestone horizon and is followed by a sandstone of variable thickness. Such a section is exposed in the south bank of Littlers Creek in the NE. ¼ sec. 29, T. 9 N., R. 3 E., as shown below:

Section of strata exposed in sec. 29, T. 9 N., R. 3 E.

	Feet
4. Sandstone	5
3. Shale, gray	35
2. Layer of septarian nodular limestone with many fossils	1
1. Shale, black, laminated with concretions or niggerheads	2½

Strata between the septarian nodular limestone and the Springfield (No. 5) coal.—The thickness of the rocks occurring in the interval between the septarian limestone associated with the black shale overlying the Colchester (No. 2) coal, and the base of the Springfield (No. 5) coal, varies from 50 to 85 feet, being greatest towards the south and east. This succession of strata is well shown in the record of a test boring for coal put down in the Blacksby School yard near the northwest corner of sec. 24, T. 6 N., R. 3 E., a partial record of which is given below:

Partial log of boring made in sec. 24, T. 6 S., R. 3 E.

		Feet
10.	Coal (Springfield or No. 5)	5¼
9.	Clay shale	2½
8.	Band of nodular limestone	1
7.	Shale, gray	12⅙
6.	Sandstone or sandy shale	25
5.	Shale, gray	47
4.	Limestone septarian, nodular, fossiliferous	½
3.	Shale, black, laminated	6
2.	Shale, gray	13½
1.	Coal (Colchester or No. 2)	2½

Other borings put down in the NW. ¼ sec. 21, and near the center of sec. 22, T. 6 N., R. 3 E., penetrated a similar succession of strata between the Springfield coal and the septarian limestone above the shale overlying the Colchester bed. Strata belonging in this interval outcrop in several places near the west side of the Canton quadrangle. In the south bank of Littlers Creek near the NW. corner of sec. 28, T. 9 N., R. 3 W., there is exposed above the septarian limestone a bed of bluish gray shale, 35 feet thick, underlying 5 feet of sandstone. In the banks of a tributary to Put Creek in the SW. ¼ sec. 7, T. 6 N., R. 3 E., there is exposed 13 feet of bluish shale, containing 1-inch bands of ironstone concretions, 1 to 2 feet apart, which corresponds to the lower part of member No. 5 of the last section. Along the private road up the hill south of this exposure the Springfield (No. 5) coal outcrops at an altitude 66 feet above the level of the septarian nodular limestone in the bed of the branch.

A bed of sandstone or sandy shale 34 feet thick, corresponding to member No. 6 of the last section, outcrops along the banks of a tributary to Coal Creek in the NE. ¼ sec. 34, T. 8 N., R. 2 E., where it is followed above by about 6 feet of bluish shale, at the top of which occurs a discontinuous band of clay ironstone concretions which is succeeded by 3 or 4 feet of underclay lying below the Springfield coal bed. The underclay and underlying band of concretions beneath the Springfield coal are exposed along Big Creek, and its tributaries in sections 9, 15, and 16, T. 6 N., R. 4 E., and in several places along Put and Coal Creeks and their tributaries.

Springfield (No. 5) coal and associated strata.—The Springfield coal is remarkably persistent in its distribution, and uniform in thickness in all of this region east of its line of outcrop, averaging 4⅔ feet in 141 well records, and 43 measured sections, and generally departing less than 6 inches from that average. In the eastern and northern portions of the Canton area, where the usual sequence of strata overlies this coal, the bed is cut by numerous clay-filled fissures (clay seams or "horsebacks") such as are characteristic of this coal in Sangamon County and in other parts of the State. In the vicinity of Cuba a sandstone immediately overlies this coal, and where such a roof is present, no clay seams have been developed.

Immediately overlying the Springfield coal there generally occurs a bed of black, laminated shale, 2 to 6 feet thick, in the lower part of which are many "niggerheads" or pyrite concretions ranging from 3 or 4 inches to as many feet in diameter.

The succession of strata for some distance above the Springfield coal outcrops along a small tributary on the east side of Big Creek, about 40 rods south of the middle of the north line of sec. 9, T. 6 N., R. 4 E., where the following section was made:

Section of strata in sec. 9, T. 6 N., R. 4 E.

	Ft.	*In.*
7. Till, pebbly	4	..
6. Shale, gray to yellow	16	..
5. Shale, gray, soft, clay with fossils	1	..
4. Limestone, nodular	..	8
3. Shale, black, laminated	2	..
2. Coal (Springfield or No. 5) with clay seams	4	9
1. Shale, gray	4	..

The Springfield coal and the overlying black, laminated shale are exposed in many places along Big Creek and its tributaries south of the Toledo, Peoria and Western railroad. These strata also outcrop in several places along Put Creek and its branches in the north half of Putnam (fig. 38) and

Fig. 38. Photograph of Springfield (No. 5) coal exposed in stripping operations 1½ miles north of Cuba.

the south half of Joshua townships. They are also well exposed in numerous places along Coal Creek and its tributaries in Fairview township, and in sections 7 and 18, in Farmington township. Still farther north a similar succession of strata outcrops along Littlers Creek and it branches in sections 21, 22, 27, 28, 35, and 36, T. 9 N., R. 3 E., in sec. 6, T. 8 N., R. 4 E., and in sections 31 and 32, T. 9 N., R. 4 E.

A typical exposure of these strata occurs along a small tributary on the east side of Big Creek in the SE. ¼ sec. 9, T. 6 N., R. 4 E., where the Springfield coal has been worked by stripping, on the land of Geo. Tyler.

Section of strata exposed in sec. 9, T. 6 N., R. 4 E.

	Feet
6. Shale, gray	23
5. Shale, gray calcareous, with fossils	1
4. Limestone, impure nodular	⅔
3. Shale, black, laminated, with niggerheads in lower part	2½
2. Coal (Springfield or No. 5)	5
1. Shale, gray clayey	2

The black laminated shale, above the Springfield coal, usually contains several fossils, the more common species of which are listed below:

Fossils from the black shale above Springfield (No. 5) Coal

Lingula umbonata Cox
Orbiculoidea missouriensis Shumard
Derbya crassa Meek and Hayden
Chonetes mesolobus Norwood and Pratten
Productus cora D'Orbigny
Marginifera muricata Norwood and Pratten
Marginifera splendens Norwood and Pratten (?)
Squamularia perplexa McChesney
Listracanthus hystrix Newberry and Worthen
Petrodus occidentalis Newberry and Worthen

The niggerheads or ironstone nodules that occur in the lower part of the black, laminated shale above the Springfield coal furnished the following fossils:

Fossils from the "niggerheads" in the black shale above the Springfield (No. 5) Coal

Lingula umbonata Cox
Orbiculoidea missouriensis Shumard
Productus cora D'Orbigny
Marginifera muricata Norwood and Pratten
Composita argentea Shepard
Solenomya parallela Beede and Rogers
Solenomya trapezoides Meek
Cardiomorpha missouriensis Shumard
Edmondia aspenwallensis Meek (?)

Fossils from the "niggerheads" in the black shale above the Springfield (No. 5) coal—Concluded

Nuculana bellistriata Stevens
Schizodus rossicus de Verneuil
Euchondria neglecta Geinitz?
Deltopecten occidentalis Shumard
Pleurophorus occidentalis Meek and Hayden
Petallostium montfortianum Norwood and Pratten
Soleniscus illinoisensis Meek and Worthen
Orthoceras rushense McChesney

The limestone cap rock, above the black, laminated shale is usually present in a single layer, 9 to 20 inches thick. In places it is somewhat concretionary, and may attain a thickness of 3 to 5 feet. It is usually overlain by 12 to 20 inches of bluish-gray, calcareous shale, known as "clod." Both the limestone and the overlying calcareous shale or "clod" contain many fossils, among which the following are common:

Fossils from the limestone and clod above the Springfield (No. 5) coal

Fossils	Sec. 21, T. 6 N., R. 3 E.	SW. ¼ sec. 8, T. 6 N., R. 3 E.	SE. ¼ sec. 7, T. 6 N., R. 4 E.	S. ½ sec. 15, T. 6 N., R. 3 E.	SE. ¼ sec. 9, T. 6 N., R. 4 E.	SW. ¼ sec. 9, T. 6 N., R. 4 E.
Lophophyllum profundum Edwards and Haime	x	x	x	....	....	x
Eupachycrinus tuberculatus Meek and Worthen	x	....	....	....	x	x
Zeacrinus sp.	....	....	....	....	x	....
Derbya crassa Meek and Hayden	x	....	x	....	x	x
Chonetes granulifer Owen	x	....	x	....	x	....
Chonetes mesolobus Norwood and Pratten	x	x	x	....	x	x
Chonetes mesolobus var. euampygus Girty	x	x	x	....	x	x
Chonetes verneuiliana Norwood and Pratten	....	x	....	....	x	....
Productus cora D'Orbigny	x	x	x	....	x	x
Productus costatus Sowerby	x	....	....	x	....	x
Productus semireticulatus Martin	....	....	....	x	x	x
Marginifera muricata Norwood and Pratten	x	x	x	x	x	x
Marginifera splendens Norwood and Pratten (?)	x	x	x	x	x	x
Pugnax rockymontana Marcou	....	x	....	....	x	....
Pugnax uta Marcou	....	x	....	....	x	....
Spirifer cameratus Morton	x	....	x	....	x	x
Spiriferina kentuckyensis Shumard	x	....	x	....	x	x
Squamularia perplexa McChesney	x	x	....	....	x	x
Ambocoelia planiconvexa Shumard	x	x	....	....	....	....
Hustedia mormoni Marcou	x	....	x	....	x	....
Cleiothyridina orbicularis McChesney	....	....	....	....	x	....
Composita argentea Shepard	x	x	x	x	x	x

Fossils from the limestone and clod above the Springfield (No. 5) coal—Concluded

Fossils	Sec. 21, T. 6 N., R. 3 E.	SW. ¼ sec. 8, T. 6 N., R. 3 E.	SE. ¼ sec. 7, T. 6 N., R. 4 E.	S. ½ sec. 15, T. 6 N., R. 3 E.	SE. ¼ sec. 9, T. 6 N., R. 4 E.	SW. ¼ sec. 9, T. 6 N., R. 4 E.
Solenomya trapezoides Beede and Rogers	....	....	....	....	x	....
Clinopistha radiata var. laevis Meek and Worthen	....	....	....	....	x	....
Edmondia sp	....	....	....	....	....	x
Nuculopsis ventricosa Hall	x	....	....	....	....	....
Leda bellistriata Stevens	....	....	....	....	x	....
Yoldia rushensis McChesney (?)	....	x	....	....	....	....
Myalina perattenuata Meek and Hayden	....	....	x	....	x	....
Aviculopecten cf. carboniferus Stevens	....	....	....	....	....	x
Allorisma subcuneatum Swallow	x	....	....	....	x	....
Allorisma sp	....	....	....	....	x	....
Astartella concentrica McChesney	....	x	....	....	x	....
Phanerotrema grayvillensis Norwood and Pratten	x	....	....	....	x	....
Phanerotrema (?) brazoensis Shumard	....	....	....	....	x	....
Trepospira illinoisensis Worthen	x	....	....	....	x	....
Bellerophon percarinatus Conrad	x	....	....	....	....	....
Euphemus carbonarius Cox	x	....	....	x	x	....
Petallostium montfortianum Norwood and Pratten	....	....	....	....	x	....
Bulimorpha nitidula? Meek and Worthen	....	....	x	....	x	....
Meekospira peracuta Meek and Worthen	....	....	....	....	x	....
Sphaerodoma brevis White	....	....	....	....	x	....
Sphaerodoma cf medalis Meek and Worthen	....	....	....	....	x	....
Sphaerodoma primogenia Conrad	x	....	....	x	....	....
Platyceras parvum Swallow	....	x	....	....	....	x
Nautilus sp	....	....	....	....	x	x
Orthoceras rushense McChesney	....	....	....	....	x	x
Griffithides scitula Meek and Worthen	....	x	....	....	....	....
Listracanthus hystrix Newberry and Worthen	....	....	....	....	x	....
Petrodus occidentalis Newberry and Worthen	....	....	....	....	x	....

The Canton shale member.—Overlying the calcareous shale above the limestone cap rock of the Springfield (No. 5) coal there is usually a bed of gray shale which is exposed in several places along Big Creek and its tributaries south of Canton. This shale may be appropriately designated the "Canton shale," as a matter of convenience for this report.

In the bank of a small stream that joins Big Creek from the east, near the middle of sec. 9, T. 6 N., R. 4 E., there are exposed the following strata which are representative of the beds above the Springfield coal in the east and north parts of the quadrangle.

Section of strata in sec. 9, T. 6 N., R. 4 E.

		Feet
5.	Shale, bluish-gray	22
4.	Shale or "clod," bluish to gray, calcareous	1¼
3.	Limestone, impure nodular	⅔
2.	Shale, black, laminated	2¾
1.	Coal (Springfield or No. 5), with clay seams	4¾

Near the city of Canton, the Canton shale member is utilized for brick making by M. Heckard and Sons (fig. 39), and the West Canton Paving

FIG. 39. Canton shale, exposed in the shale pit of M. Heckard and Son, near Canton.

Brick Company. In the shale pit of the latter company a thickness of 30 feet is dug, but the upper 13 feet contain layers of sandstone and sandy shale that are discarded.

Strata between the Canton shale and the Herrin (No. 6) coal.—The sandstone above the Canton shale member is well exposed in the east bank of Big Creek, ¼ mile below the bridge of the Toledo, Peoria and Western Railroad, where 4 to 6 feet of sandstone are seen overlying 14 feet of gray, sandy shale. A sandstone generally overlies the Canton shale in this region, and is followed by 6 to 8 feet of gray to yellow shale and this, in turn by 1 to 3 feet of clay shale underlying the Herrin (No. 6) coal bed. Strata underlying the Herrin coal are exposed in a ravine near the middle of the S. ½ sec. 4, T. 8 N., R. 4 E., as shown in the following section:

Section of strata exposed in the S. ½ sec. 4, T. 8 N., R. 4 E.

	Feet
7. Limestone, gray, containing *Girtyina ventricosa*	2
6. Shale, dark	½
5. Coal, with "blueband" (Herrin or No. 6 bed)	4
4. Shale, gray, clayey	3
3. Shale, sandy	5
2. Sandstone, gray	5
1. Shale, bluish-gray, to water level	7

Strata between the Springfield (No. 5) and Herrin (No. 6) coals near Cuba.—The thickness and character of the strata occurring in the interval between the Springfield and the Herrin coal beds in the north part of the area are quite similar to those in the east half of the Canton quadrangle, but in the southwest quarter of this quadrangle the interval between these coals is less, and the strata are much more variable. In the vicinity of Cuba and Fiatt the Canton shale member is usually in part or entirely absent, and the limestone cap rock is often directly overlain by sandstone. In some places the cap rock is also absent, and the black laminated shale overlying the coal, may also be wholly or in part wanting (see fig. 38). In these places a sandstone rests directly upon the Springfield coal, or upon some level of the overlying black laminated shale, or upon the cap rock above the shale. In rare cases all the strata normally occurring between the Springfield and the Herrin coals are wanting, and more rarely a part or all of the Springfield coal is also absent.

The relations of the strata in this region are shown in the following detailed sections:

The record of a boring about six miles southwest of Canton in the NE. ¼ sec. 10, T. 6 N., R. 3 E., indicates that there the Herrin coal rests directly upon the Springfield bed as shown below:

Log of boring in the NE. ¼ sec. 10, T. 6 N., R. 3 E.

	Feet
Soil and clay	31
Shale	19
Sandstone	3
Shale	4½
Limestone	1⅓
Shale	⅓
Coal	10
Clay, shale, and sandstone	2⅔

About two miles southwest of the boring described above, a thickness of 7½ feet of strata occurs between these coals, as shown in the following section:

Section of strata exposed along a stream in SE. ¼ sec. 8, T. 6 N., R. 3 E.

	Feet
8. Limestone, gray, in layers 6 to 10 inches thick, containing *Girtyina ventricosa* and other fossils	4
7. Shale, dark gray	⅓
6. Coal (Herrin or No. 6 bed), with a 2-inch "blueband" 14 inches above the bottom	4
5. Shale, gray, clay	½
4. Sandstone, yellowish-gray, micaceous	5
3. Shale, black, laminated	2
2. Coal (Springfield or No. 5 bed)	4½
1. Gray clay shale	1½

In a ravine about ¼ mile west of the place where the last section was made an interval of 16 feet was measured between these coals, as shown in the section given below:

Section of strata in the SW. ¼ SE. ¼ sec. 8, T. 6 N., R. 3 E.

	Feet
9. Shale, gray	2
8. Limestone, gray, in layers 4 to 8 inches thick, containing *Girtyina ventricosa* and other fossils	4
7. Shale, dark gray	1½
6. Coal (Herrin or No. 6 bed), with "blueband" 1½ inches thick 14 inches above the bottom	5½
5. Concealed, about	8
4. Limestone, gray, nodular	1
3. Shale, black, laminated	7
2. Coal (Springfield or No. 5) bed	4½
1. Shale, gray, clayey	1½

About half a mile west of the exposure last described, in the SW. ¼ sec. 8, of the same township the following succession of strata outcrop in the west bank of a creek:

Section of strata exposed in the SW. ¼ of sec. 8, T. 6 N., R. 3 E.

	Feet
4. Sandstone, yellowish-gray, micaceous	9
3. Shale, bluish-gray, calcareous, with nodules of limestone, probably the residual part of the decomposed cap rock	1
2. Shale, black, laminated	2½
1. Coal (Springfield or No. 5 bed)	4½

In several places in the banks of this creek, both north and south of mine No. 2 of the Star Coal Company, a sandstone equivalent to the upper member in the last section is exposed above the black shale overlying the Springfield coal. Frequent outcrops of these strata also occur in the SW. ¼ sec. 7, T. 6 N., R. 3 E. Along a ravine ½ mile south and ½ mile west of the cemetery at Cuba the interval between the top of the Springfield coal and the bottom of the Herrin bed is 22 feet. A boring put down a

short distance south of the northeast corner of section 20, in Putnam township, showed about 35 feet of sandstone and shale between these coals as follows:

Log of boring near the NE. corner of sec. 20, T. 6 N., R. 3 E.

	Feet
Soil and clay	18
Clod	1
Coal (Herrin or No. 6 bed)	5¼
Shale, gray	6
Sandstone, hard	28½
Shale, black	1
Coal (Springfield or No. 5 bed)	5

A boring near the center of section 29 of the same township found no coal where the Springfield bed should occur below 14 feet of sandstone. Another boring in the northeast ¼ of section 28 of this township found the Springfield coal only 3 feet thick, below 25 feet of sandy shale. Along a stream half a mile to a mile north of Fiatt Station, in sections 21 and 28, T. 7 N., R. 3 E., a bed of sandstone lies very close to the top of the Springfield coal, as shown in an exposure in the SE. ¼ sec. 21, where the following section was made:

Section of strata outcropping in the SE. ¼ of sec. 21, T. 7 N., R. 3 E.

	Feet
4. Sandstone, yellowish-gray, micaceous	5
3. Shale, black, laminated, in places cut out so that the sandstone rests directly upon the coal, but usual thickness of	1½
2. Coal (Springfield or No. 5 bed)	5
1. Clay shale	1

At a place where the Springfield coal was formerly mined along a ravine in the NW. ¼ section 28 of the same township, the following succession of strata are exposed:

Section of strata exposed in the NW. ¼ sec. 28, T. 7 N., R. 3 E.

	Feet
3. Sandstone, yellowish-gray, micaceous	6
2. Shale, black laminated	2
1 Coal (Springfield or No. 5 bed)	5

The unusual variation in the succession and thickness of the strata between the Springfield and Herrin coals in the southwest quarter of the Canton quadrangle, as shown in the foregoing sections, indicates local warping and erosion in this region which probably occurred during the latter part of the time of deposition of the strata of this interval, after the Canton shale member was laid down. It is thought that the sandstone that north of Cuba immediately overlies the Springfield coal, or some level of the black, laminated shale or the overlying cap-rock, represents the same sandstone that lies above the Canton shale in the east and north parts of the Canton quadrangle.

Herrin (No. 6) coal.—The Herrin coal, which is the youngest member of the Carbondale formation, is present over 35 or 40 square miles in the northeast quarter of the Canton quadrangle, extending south within 2 miles of Canton and west as far as Fairview. It is also present in small patches northeast of Cuba in the southwest quarter of this quadrangle. The approximate outcrop of this coal in the area is indicated on the structure map, Plate I. The Herrin coal is 4 to 5½ feet thick, and is distinguished by a band of dark, shaly or bony coal ("blue band") one to two inches thick, thirteen to fifteen inches above the floor of the bed.

MCLEANSBORO FORMATION

General character of the rocks.—The McLeansboro formation, which embraces all of the Pennsylvanian strata above the Herrin (No. 6) coal, was named from the town of McLeansboro, in Hamilton County, where the strata belonging to this formation have a thickness of 1,000 or more feet. They consist largely of shale and sandstone, with some thin limestones and a few coals, none of which is of workable thickness. The maximum known thickness of this formation in the Canton quadrangle is about 85 feet.

Fig. 40. Herrin (No. 6) coal and cap-rock, exposed along Copperas Creek, 2 miles east of Brereton.

Strata between the Herrin (No. 6) and the No. 7 coals.—The Herrin coal (see fig. 40) in this are is generally overlain by a bluish to dark

calcareous shale 6 to 14 inches thick, above which is a bed of gray limestone 3½ to 4 feet thick, containing *Girtyina ventricosa* and other fossils listed below:

Fossils from the limestone above the Herrin coal

Fossils	NW. ¼ sec. 15, T. 7 N., R. 4 E.	Near Middle N. ½ sec. 1, T. 8 N., R. 3 E.	SW. ¼ sec. 15, T. 7 N., R. 4 E.	SE. ¼ sec. 1, T. 7 N., R. 4 E.	SE. ¼ sec. 36, T. 8 N., R. 4 E.
Girtyina ventricosa Meek and Hayden	x	x	x	x	x
Lophophyllum profundum Edwards and Haime	x	x	x	x	x
Zeacrinus mucrospinus McChesney	x	..	?	?	x
Derbya crassa Meek and Hayden	x	x	..	x	x
Chonetes granulifer Owen	x	x	..	x	x
Chonetes mesolobus Norwood and Pratten	x	x	x	x	x
Chonetes verneuiliana Norwood and Pratten	x	..	x	..	..
Productus cora D'Orbigny	..	x	..	..	..
Productus costatus Sowerby	x	..	..	x	x
Productus cf. pertenuis Meek	..	..	..	..	x
Productus semireticulatus Martin	x	..	x	..	..
Pustula semipunctata (Martin)	x	..	..	..	x
Marginifera muricata Norwood and Pratten	x	..	..	..	..
Marginifera splendens Norwood and Pratten	x	x	x	x	x
Pugnax uta Marcou	x	x	x	x	x
Spirifer cameratus Morton	x	..	x	x	x
Spiriferina kentuckyensis Shumard	x	x	..	x	x
Squamularia perplexa McChesney	..	..	x	x	..
Hustedia mormoni Marcou	x	..	x	x	..
Cleiothyridina orbicularis McChesney	x	..	..	..	x
Composita argentea Shepard	x	x	x	x	x
Petrodus occidentalis Newberry and Worthen	x	x	..	..	x

Overlying the limestone cap rock of the Herrin coal there is usually 10 to 15 feet of shale which is followed by a few feet of sandstone and this in turn by about 14 feet of gray and blue shale, some parts of which are mottled with pink and red. This shale is overlain by No. 7 coal which has a thickness of about eighteen inches. The interval between the Herrin (No. 6) coal and No. 7 coal is 33 to 36 feet. All of the strata of this interval are penetrated in test borings near the east border of the northeast quarter of the quadrangle. They are well exposed in the south bank of a creek in the NW. ¼ of sec. 1, T. 7 N., R. 4 E., where the following section was made:

Section of strata exposed in sec. 1, T. 7 N., R. 4 E.

		Feet
9.	Coal (No. 7)	1½
8.	Shale, gray and red	14
7.	Sandstone, micaceous gray	3
6.	Shale, gray, more or less sandy	12
5.	Limestone, gray, in layers 4 to 30 inches thick, containing *Girtyina ventricosa* and other fossils	5
4.	Shale, gray to dark	½
3.	Coal (Herrin or No. 6 bed), with a 2-inch "blueband" 16 inches above the floor	4¾
2.	Shale, gray to blue clayey	3½
1.	Sandstone, and sandy shale	6

No. 7 coal and overlying strata.—The thin No. 7 coal, overlying the gray and red shale, is 9 to 20 inches thick and is not utilized in any place in this area. In the vicinity of Farmington there are present above the No. 7 coal about 40 feet of gray shale, followed by 10 or 12 feet of dark shale which is overlain by 6 or 8 feet of gray limestone, occurring in two ledges separated by 12 to 18 inches of gray calcareous shale. This limestone is correlated with the Lonsdale limestone of the Peoria region. It is present only over a limited area of the upland in the northeast quarter of the Canton

Fig. 41. Lonsdale limestone, exposed in an old quarry 2½ miles east of Farmington.

quadrangle. It outcrops along a small stream two and one-half miles east of Farmington where the following strata are exposed, as shown in figure 41:

Section of strata 2½ miles east of Farmington

		Feet
7.	Loess	3
6.	Till, yellowish	4
5.	Shale, gray	4
4.	Limestone, gray, in rough, uneven layers 8 to 12 inches thick	5
3.	Shale, gray, calcareous, with small calcareous nodules	7
2.	Limestone, gray	4
1.	Shale, dark	7½

The following fossils were collected from this limestone:

Fossils from the Lonsdale limestone exposed 2½ miles east of Farmington

Lophophyllum profundum Edwards and Haime
Campophyllum torquin Owen
Eupachycrinus tuberculatus Meek and Worthen
Derbya crassa Meek and Hayden
Chonetes granulifer Owen
Chonetes mesolobus Norwood and Pratten
Productus cf. punctatus Martin
Productus semireticulatus Martin
Pustula semipunctata Martin
Marginifera splendens Norwood and Pratten
Rhynchonella illinoisensis Worthen
Pugnax uta Marcou
Cryptacanthia compacta White and St. John
Dielasma bovidens Morton
Spirifer cameratus Morton
Spiriferina kentuckyensis Shumard
Squamularia perplexa McChesney
Hustedia mormoni Marcou
Cleiothyridina orbicularis McChesney
Composita argentea Shepard
Straparollus (?) sp.
Loxonema (?) sp.
Strophostylus peoriense McChesney
Strophostylus cf. remex White
Griffithides scitula Meek and Worthen

The limestone described above is the youngest of the Pennsylvanian rocks known in the quadrangle. It corresponds to the limestone worked in the Lonsdale quarry, a few miles farther east in Peoria County, and is the equivalent of the limestone outcropping along Rock Creek in Menard County.

Structure

The term structure refers to the attitude of the rocks, that is, whether horizontal, inclined, folded, or faulted; and to the direction and amount of

displacement of the faults, and the direction and the amount of inclination or dip of the strata. A knowledge of the structure of the coal beds and associated strata in any locality is essential to an intelligent estimate of the cost of mining, and the wise selection of the location for mine shafts. The deformation and dip of the coal beds, as well as the character of the associated strata, very materially affect the expense of drainage, and the cost of timbering and haulage.

GENERAL DESCRIPTION

The structure of the strata in the Avon quadrangle, and in that portion (No. 5) coal, as shown on the structure map, is based on the elevation of No. 2 coal above sea level. The data were obtained mainly from the elevation of outcrops of this coal, as determined by leveling with hand level to the nearest bench mark, and from the records of water wells and test borings in which this bed was encountered. The elevation at which No. 2 coal should occur, if it had been present, was also obtained at several points by adding to the elevation of No. 1 coal, as determined in outcrops and borings, a number corresponding to the thickness of the strata occurring between No. 1 coal and No. 2 coal, which in this part of the state is about 56 feet.

The structure of the strata in that portion of the Canton quadrangle east of the line of outcrop of the Springfield (No. 5) coal, as shown on the structure map, Plate I, of this report, is based on the Springfield (No. 5) coal. The data for the construction of this portion of the map were obtained, for the most part, from the elevation of the Springfield coal at the numerous outcrops and from the logs of water wells, test borings, and mine shafts which pass through this coal, as in the altitude determinations of No. 2 coal. In the places where outcrops of the Herrin (No. 6) coal occur, the elevation of this coal was found by leveling to the nearest bench mark. The elevation of the Springfield coal at those places was then computed by subtracting from the elevation of the Herrin coal a number corresponding to the thickness of the strata occurring between the Springfield and the Herrin coals. In the eastern and northern portions of the Canton quadrangle, this interval does not vary far from 65 feet, but in the southwest quarter the interval is very much less.

The coal beds, and the intervals between them vary somewhat in thickness, yet over the greater part of the area the strata lie essentially parallel. The layers are not generally horizontal, but dip in different directions and at various angles in different parts of the quadrangle. The general dip and altitude of No. 2 coal, and the Springfield (No. 5) bed in different places are shown on the structure map by the use of contour lines. The outcrops and the locations of the borings and shafts, the records of which furnished data used in the construction of the structure map, are shown on the geologic map, Plate I.

Between adjacent points at which the coal was found to lie at different altitudes, the dip is assumed to be uniform. Hence on the structure map, a line connecting all the known points at which No. 2 coal occurs at an elevation of 580 feet above sea level, constitutes the 580-foot contour line. In the same manner all of the points at which this coal was found to lie 600 feet above the sea, are connected by the 600-foot contour line, and so on. A dip of 20 feet is indicated between any two adjacent contour lines.

The assumption of a uniform dip for the coal bed between points where it is found at different elevations is a source of slight error in a map constructed in this manner. Local changes in the dip of the strata, and low domes and folds were found in some of the coal mines, and seen in a few surface exposures. The details of these local irregularities of small magnitude do not appear on a structure map of this kind.

The probability of error in the map is greater where the outcrops, mine shafts, and test holes of which records were obtained are a considerable distance apart, as over the interstream areas east of Spoon River, between Coal Creek and Littlers Creek on the north, and Coal Creek and Put Creek on the south; and west of the river, between Swan and Cedar creeks on the north and Shaw and Shoal creeks on the south. Over such areas where the data are not sufficient to give reasonably certain information concerning the structure, the contour lines are broken. However, it is practically certain that the general lay of the coals, and thus the general structure of the Pennsylvanian rocks in this area, is essentially as shown on the structure map. From this map it will be seen that in the eastern part of the Canton quadrangle, the rocks have a general, rather gentle dip in an eastward direction. A somewhat irregular dome in the southwest quarter of this area is continued eastward as a low anticline along the southern part of the quadrangle. A more pronounced dome in the northwest quarter is also continued eastward as a small arch near the town of Farmington. In the Avon quadrangle, the rocks also have a general eastward dip, which is disturbed in the northwest quarter by an anticline trending nearly north and south to the elbow of Swan Creek whence it continues toward the southeast beyond Babylon. The structure becomes quite irregular on the southern part of the Avon quadrangle where a small arch is formed on the west side of the low domelike structure that extends into the southwest quarter of this quadrangle from the Canton area. The average dip of the strata in these areas probably does not exceed 10 feet per mile, although in places the inclination is as much as 40 or more feet per mile.

PRACTICAL USE OF THE STRUCTURE MAP

The practical value of the accompanying structure map, Plate I, will appear from the fact that, when used in connection with the topographic map of the area, the approximate depth below the surface of Murphysboro

(No. 2) coal or the Springfield (No. 5) bed at any point over the respective areas in which one or the other is used as the key stratum, may be readily ascertained. On the structure map, the distribution of the Springfield coal is shown, and also the area underlain by No. 2 coal, outside the area of the Springfield bed. From the contour lines on this map the elevation above sea level of No. 2 coal, or the Springfield (No. 5) coal, in the respective areas at any point can be readily found. The topographic map shows by contour lines the height above sea level of the surface of the area. From this map the surface elevation of any point in the quadrangles can be approximately determined. Subtracting from this surface elevation the altitude of No. 2 coal, or No. 5 coal, at that place, as found from the structure map, the remainder will represent the approximate depth of the coal bed beneath the surface at that point.

The direction of dip of the strata is assumed to be at right angles to the contour lines. The steepness of the slope is indicated by the distance between adjacent contour lines. A difference in elevation of 20 feet is shown by adjacent lines, so that the closer together the lines appear, the steeper is the dip, and the wider the distance between the lines the more gentle is the slope of the strata in that region.

MINERAL RESOURCES

Besides the soil, which is the greatest source of wealth in the area, and the water which is indispensable, coal is the most important natural resource of the Avon and Canton quadrangles. Four different coal beds are in places worked in this area, and there is scarcely a square mile that is not underlain by one or more workable beds. Next to coal in importance are clay and shale, the supply of which is practically inexhaustible. Sand, gravel, and building stone occur in some places, and oil and gas may possibly also be present.

Coal

The Avon and Canton quadrangles lie in the northwest part of the Eastern Interior coal basin (see fig. 33), in the region in which the Herrin and Springfield coal beds are about equal in thickness. During the year 1920 the coal mined in this area inclusive of a belt less than one mile wide bordering the south side, aggregated about 2,220,000 tons, more than 95½ per cent of which was produced by the 25 commercial (shipping) mines, 19 of which were within the borders of the Canton quadrangle. Besides these shipping mines there were 60 odd local (wagon) mines, mostly drifts and strippings, that were worked during only a small part of the year.

Practically all of the coal output of the Canton quadrangle is taken from the Springfield bed, but in a few places near the eastern side of the quadrangle the Herrin (No. 6) coal is in places also worked to supply local

trade. In the Avon quadrangle the Rock Island (No. 1) and the Colchester (No. 2) beds furnish all of the coal.

POTTSVILLE COALS

ROCK ISLAND (NO. 1) COAL

The most important coal in the Pottsville formation is the Rock Island bed which is thought to be the equivalent of the coal mined in Rock Island County, Illinois, and of the "Pocket" coal lying 50 to 70 feet below the top of the Pottsville in Jackson County, and is also probably about the age of the Mercer coal of the Appalachian region. It is well known in its outcrops along Spoon River in the vicinity of Seville where its thickness is 3 to 4½ feet. It has been mined in a small way at a few places near Seville, and is at present worked by a drift at Leaman Station a few miles farther southwest where the thickness is 2½ feet. In the vicinity of Ellisville, where this coal is 4 to 5 feet thick, it is worked by the Riverview Coal Company in a shaft about 40 feet deep. The only commercial mine in the area at present working this coal is that of the Spoon River Coal Company at Ellisville Station. The depth to the coal at this place is about 35 feet, and the thickness of the bed 3 to 5½ feet. The Rock Island coal is also mined by a slope in the SW. ¼ sec. 10, T. 8 N., R. 2 E., where its thickness averages about 4 feet. It is worked by drifts in several places along Aylesworth branch and its tributaries in secs. 11 and 14, T. 7 N., R. 1 E., and farther south in the vicinity of Babylon. At London Mills, where this coal is 34 inches thick, it is worked intermittently in a shaft mine 45 feet deep.

Where the bed is well developed this coal is of good quality, but on account of its irregularity in thickness, varying from 1 to 6 feet within relatively short distances, it has not been extensively worked. The Rock Island coal is generally present in this region except over a few square miles near the northwest corner of the Avon quadrangle, from which it has been eroded, and smaller areas, as in sec. 13, T. 8 N., R. 1 W., and sec. 18, T. 8 N., R. 1 E., over which it seems never to have been deposited. It usually lies about 45 feet above the base and 35 to 55 feet below the top of the Pottsville formation in this region, although in some records it is reported as not more than 25 feet below the No. 2 bed. This coal is usually overlain by a hard limestone which furnishes an excellent roof.

COAL BELOW THE ROCK ISLAND (NO. 1) BED

In a number of places in the Avon quadrangle a coal bed 1 to 2½ feet thick is present only a few feet below the Rock Island bed, and is usually overlain by sandstone. This coal has been mined by drifts in a few places, as in sec. 31, T. 9 N., R. 1 E., sec. 13, T. 8 N., R. 1 W., and sec. 18, T. 8 N., R. 1 E. At the latter locality the bed is about 14 inches thick and resembles

cannel coal. Many years ago it was extensively worked for the distillation of coal oil, in which process 10 retorts were at one time in operation. Thirty gallons of oil are said to have been produced from one ton of coal. At that time the clay underlying the coal was also mined and manufactured into fire brick.[1] A coal bed belonging to this horizon is also well exposed in the banks of Cedar Creek in secs. 23 and 26, T. 9 N., R. 1 W.

COALS BETWEEN THE ROCK ISLAND (NO. 1) AND COLCHESTER (NO. 2) BEDS

In some places in this region two coal beds aggregating about 3 feet in thickness and separated by 3 to 6 feet of shale occur 8 to 15 feet above the Rock Island coal. Another very persistent coal, 10 to 14 inches thick, is generally present about 25 to 28 feet above the Rock Island bed, and is overlain by several feet of soft shale. None of these coals has been worked in this region.

CARBONDALE COALS

COLCHESTER (NO. 2) COAL

The lowest coal bed of the Carbondale formation is the No. 2, which is possibly identical with the Murphysboro coal in Jackson County, although in the Avon quadrangle it is nowhere divided into two benches as it commonly is in the vicinity of Murphysboro. It apparently corresponds with the bed mined at Colchester, and probably with the "third vein" coal near La Salle, and with No. 2 coal in the vicinity of Morris and Braidwood, in the northeast part of the Illinois coal basin. The Colchester coal is generally present in this region except in the northwest quarter of the Avon quadrangle from which it has been removed by erosion. It is remarkably uniform in thickness, ranging from 28 to 32 inches, and known locally as the "30-inch" bed. This bed supplies most of the coal used in the towns of St. Augustine, Avon, and Prairie City. It has been mined by drifts in many places along Swan Creek and its tributaries west of Avon, in secs. 23 and 26, T. 8 N., R. 1 W. At the latter locality the coal was 28 inches thick and was formerly worked by means of a shaft 53 feet deep. The shale overlying the coal was also mined and manufactured into brick.

In many places along Shaw and Shoal creeks and their branches, this coal has been and is at present mined by drifts to supply local demand. In the eastern part of the Avon quadrangle a number of drift mines also work this bed in secs. 28 and 29, T. 9 N., R. 2 E., and it has been stripped in a few places along the streams in sec. 22, T. 8 N., R. 2 E., and in the SW. ¼ sec. 27, T. 7 N., R. 2 E. The coal is overlain by 12 to 20 feet or more of soft shale which makes a very troublesome roof.

NO. 3 COAL

The position of the No. 3 coal bed described by Worthen in the geology of Fulton County appears to be immediately associated with the

[1]Worthen, A. H., Geological Survey of Illinois, vol. IV, p. 105, 1870.

septarian nodular limestone about 12 to 20 feet above the Colchester (No. 2) bed, but no coal is present at this horizon in the Avon and Canton quadrangles.

NO. 4 COAL

The coal in this region described by Worthen as No. 4 corresponds to the bed that is known as No. 5 or Springfield coal over the greater part of the State. The Springfield coal in this region is generally about 65 feet below the Herrin. North of Cuba, Worthen found a coal, 4 feet thick, about 30 feet below the Herrin bed, and thought that this represented a coal belonging between the coal 65 feet below the Herrin (No. 6) bed north of Canton and the Herrin coal. Hence, he called the coal north of Cuba, 30 feet below the Herrin bed, No. 5 coal, and the coal in the vicinity of Canton, 65 feet below the Herrin bed, No. 4 coal. It is now known that locally erosion occurred during some part of the time of deposition of the sediments usually present between the Springfield and the Herrin coals, which in places, as in the vicinity of Cuba, removed a large part of the strata that generally occur in this interval, and that the coal north of Cuba, Worthen's No. 5, ranging from a few to 30 or more feet below the Herrin is the equivalent of the Springfield coal 65 feet below the Herrin coal in the vicinity of Canton which Worthen called No. 4 coal.

SPRINGFIELD (NO. 5) COAL

The Springfield coal, known as No. 5, furnishes practically all of the coal mined in the Canton quadrangle, only a few local mines being operated in the Herrin (No. 6) bed during a small part of the year. This bed is the equivalent of the coal mined in the vicinity of Springfield, and probably corresponds with the Harrisburg bed in southeast Illinois. It also corresponds to the "middle vein" coal in the vicinity of La Salle. It is a very persistent bed, being present over practically all of the Canton quadrangle east of its line of outcrop, and underlies an extensive territory to the south and east of this area. Its thickness is remarkably uniform (from 4 to 5 feet) in the different mines and outcrops of the area. In the eastern and north parts of the Canton quadrangle the Springfield coal lies about 65 feet below the Herrin bed, but in the southwest quarter, in the vicinity of Cuba, an erosional unconformity occurred between these coals so that in some places, a variable part of the strata usually present between these coals, has been removed by erosion and the Springfield coal is locally found only 8 to 25 feet or less below the Herrin bed.

As elsewhere in the State the Springfield coal in this region is usually cut by numerous clay seams or "horsebacks" which in some places increase the trouble and expense of mining and cleaning the coal. In the southwest part of the area, where the strata usually occurring above the Springfield bed are absent, and the coal is immediately overlain by several feet of sand-

stone, there are no clay seams in the coal. This fact corroborates the views previously expressed[1] that the character of the strata associated with the coal determined the formation of the clay seams.

The conditions for mining the Springfield coal are unusually favorable. The underclay is hard and generally thin and does not creep readily so that it rarely causes trouble by squeezes. The coal is overlain by a hard black shale that usually stands well as a roof without much timbering, except in the vicinity of the clay seams. In the lower part of the roof shale "niggerheads" or pyrite concretions are in many places abundant.

The composition and fuel value of this coal are given in the table of analyses.

HERRIN (NO. 6) COAL

The Herrin coal is present in the area over only 35 or 40 square miles near the east side of the Canton quadrangle north of Canton, and over a still smaller area in the vicinity of Cuba. It lies so near the surface, usually from a few feet to 50 feet, that its quality has been injured by the action of ground water, so that even when it is present the shafts of the commercial mines are put down through this coal to the Springfield bed which is normally about 65 feet lower. The Herrin coal is fairly uniform in thickness in this region, usually ranging between 4 and 5 feet. As elsewhere in the State this coal has a band of bone coal or dark shale ("blue band"), 1 to 2 inches thick, about 14 inches above the floor. Like the Springfield and other coals in this region and at other places in the State, the Herrin coal appears laminated or banded with alternating bright and dull laminæ which vary in thickness from ¼ to 1-32 of an inch, the thickness of the bright laminæ not differing greatly from that of the dull. The dull bands usually contain mineral charcoal or mother coal which at some levels, especially in the upper part of the bed, is sufficiently thick to form conspicuous, clean, persistent partings.

Above the coal is a few inches of dark shale followed by a hard limestone 3 to 5 feet thick which contains numerous shells of *Girtyina ventricosa* and other marine fossils. The underclay of this coal is hard and generally 1 to 3 feet thick, and when the coal is worked causes little trouble by squeezing.

McLEANSBORO COAL

NO. 7 COAL

In this region No. 7 coal, measuring 12 to 18 inches, is too thin to be profitably mined. It is present over only 20 or 25 square miles near the east side of the Canton quadrangle, in the vicinity of Farmington and south as far as Brereton. It lies about 35 feet above the Herrin coal and about 105 feet above the Springfield bed, and is the uppermost coal that is found in this region.

---

[1]T. E. Savage, Clay seams or "horsebacks" near Springfield, Illinois: Economic Geology, vol. V, No. 2, March, 1910, pp. 178-187.

CHEMICAL ANALYSES OF THE COALS

Samples of coal for chemical analysis have been collected by representatives of the Illinois Geological Survey from the face of the Springfield coal in the mines of the Canton quadrangle. The results of these analyses are given in the table below:

TABLE 42.—*Analyses of mine samples taken in and near the Canton and Avon quadrangles*

Not exactly indicative of commercial output

Laboratory No.	File No.[a]	Date	Coal Bed	Proximate Analysis of Coal 1st: "As rec'd," with total moisture 2nd: "Dry" or moisture free				Sulphur	CO_2	B. t. u.	Unit Coal
				Moisture	Volatile Matter	Fixed Carbon	Ash				
				No. 1 Coal							
12469	0328	4/21	1	11.38	38.66	39.51	10.45	4.52	.87	11436	
				Dry	43.62	44.58	11.80	5.10	.98	12905	14979
12470	0328	4/21	1	11.42	38.17	40.07	10.34	4.76	.45	11409	
				Dry	43.09	45.24	11.67	5.37	.51	12880	14934
12471	0328	4/21	1	10.84	38.42	40.91	9.83	5.61	.54	11554	
				Dry	43.09	45.88	11.03	6.29	.61	12959	14939
1858	0328	9/08	1	17.21	37.49	38.69	6.61	3.90	....	11147	
				Dry	45.28	46.73	7.99	4.71	....	13464	14904
				No. 2 Coal							
2753	1422	....	2	14.87	35.80	43.88	5.45	....	....	11641	
				Dry	42.06	51.54	6.40	3.69	....	13674	14083
				No. 5 Coal							
12442	0102	4/21	5	15.43	33.62	39.47	11.48	2.50	1.41	10389	
				Dry	39.76	46.67	13.57	2.66	1.67	12285	14473
12443	0103	4/21	5	14.43	34.60	39.09	11.88	2.82	2.45	10320	
				Dry	40.43	45.69	13.88	3.29	2.86	12061	14297
12444	0103	4/21	5	15.00	33.10	37.31	14.59	3.38	2.86	9834	
				Dry	38.94	43.89	17.17	3.98	3.36	11569	14300
12445	0103	4/21	5	14.69	34.07	40.18	11.06	2.83	1.75	10383	
				Dry	39.94	47.09	12.97	3.32	2.05	12172	14266
12446	0103	4/21	5	14.52	34.46	37.64	13.38	2.91	2.74	10045	
				Dry	40.31	44.04	15.65	3.40	3.21	11752	14261
12447	0103	4/21	5	14.75	33.18	38.89	13.18	3.70	1.54	9869	
				Dry	38.92	45.62	15.46	4.34	1.81	11577	14298
12448	0103	4/21	5	14.28	34.93	38.76	12.03	2.56	1.98	10329	
				Dry	40.75	45.22	14.03	2.99	2.31	12061	14316
12472	0104	4/21	5	15.32	35.12	38.05	11.51	2.59	1.41	10482	
				Dry	41.48	44.93	13.59	3.06	1.66	12379	14617
12473	0104	4/21	5	15.09	13.37	39.41	10.13	2.68	1.79	10741	
				Dry	41.66	46.41	11.93	3.16	1.66	12650	14631

[a] Analyses having the same file number are for the same mine. Attention is called to the fact that much greater dependence can be placed on these analyses where there are at least three for a given mine than where only one is available.

TABLE 42—*Continued*

Laboratory No.	File No.[a]	Date	Coal Bed	Proximate Analysis of Coal 1st: "As rec'd," with total moisture 2nd: "Dry" or moisture free				Sulphur	CO_2	B. t. u.	Unit Coal
				Moisture	Volatile Matter	Fixed Carbon	Ash				
12474	0104	4/21	5	15.56	35.68	38.92	9.84	2.43	1.33	10753	
				Dry	42.26	46.09	11.65	2.88	1.58	12735	14668
12475	0104	4/21	5	14.56	35.37	38.98	11.09	2.72	1.38	10581	
				Dry	41.40	45.62	12.98	3.19	1.62	12384	14512
12476	0104	4/21	5	15.39	33.82	38.77	12.02	3.40	1.67	10338	
				Dry	39.97	45.82	14.21	4.02	1.97	12219	14565
12477	0104	4/21	5	15.66	34.65	37.56	12.13	2.93	1.88	10242	
				Dry	41.08	44.54	14.38	3.47	2.23	12144	14583
12439	0111	4/21	5	13.37	36.03	39.03	11.57	3.06	1.46	10787	
				Dry	41.59	45.06	13.35	3.52	1.69	12452	14670
12440	0111	4/21	5	14.44	34.71	38.58	12.27	2.17	1.80	10578	
				Dry	40.57	45.09	14.34	2.54	2.10	12364	14683
12441	0111	4/21	5	14.96	33.65	39.96	11.43	4.32	1.11	10502	
				Dry	39.57	46.99	13.44	5.08	1.30	12352	14616
5345	0115	8/12	5	16.36	33.91	38.19	11.54	2.93	1.27	10186	
	C30			Dry	40.54	45.66	13.80	3.50	1.51	12179	14431
5346	0115	8/12	5	16.33	35.50	37.01	11.16	2.89	1.84	10220	
	C30			Dry	42.42	44.23	13.35	3.45	2.20	12213	14389
5347	0115	8/12	5	15.85	36.12	38.12	9.91	3.36	1.47	10494	
	C30			Dry	42.92	45.30	11.78	4.00	1.75	12471	14386
5293	0127	8/12	5	17.13	36.23	34.44	12.20	3.03	1.79	9846	
	C29			Dry	43.72	41.55	14.73	3.66	2.16	11882	14252
5297	0127	8/12	5	16.59	35.98	37.20	10.23	4.07	1.77	10271	
	C29			Dry	43.14	44.61	12.25	4.88	2.12	12314	14354
5300	0127	8/12	5	15.41	35.67	39.04	9.88	3.31	.52	10579	
	C29			Dry	42.16	46.15	11.69	3.92	.61	12505	14443
12459	0134	4/21	5	14.57	35.24	39.58	10.61	2.89	1.00	10562	
				Dry	41.25	46.33	12.42	3.38	1.17	12363	14391
12460	0134	4/21	5	16.16	35.65	37.89	10.30	2.50	1.56	10422	
				Dry	42.52	45.19	12.29	2.98	1.86	12431	14434
12461	0134	4/21	5	13.35	37.84	39.86	8.95	2.22	1.77	10843	
				Dry	43.67	46.00	10.33	2.56	2.04	12514	14150
12462	0134	4/21	5	15.86	35.20	37.32	11.62	3.49	1.31	10198	
				Dry	41.84	44.35	13.81	4.15	1.56	12120	14380
12463	0134	4/21	5	14.34	35.09	36.72	13.85	3.84	2.47	9944	
				Dry	40.96	42.87	16.17	4.48	2.89	11609	14217
12464	0134	4/21	5	14.62	36.18	39.21	9.99	2.43	1.49	10719	
				Dry	42.38	45.92	11.70	2.85	1.74	12555	14465
5292	0811	8/12	5	17.39	37.00	35.69	9.92	2.74	1.14	10273	
	C28			Dry	44.79	43.20	12.01	3.28	1.36	12435	14416
5295	0811	8/12	5	16.33	36.27	36.58	10.82	3.40	1.94	10246	
	C28			Dry	43.34	43.72	12.94	4.06	2.32	12247	14371
5299	0811	8/12	5	16.33	36.75	38.02	8.90	2.59	1.02	10604	
	C28			Dry	43.92	45.44	10.64	3.10	1.22	12674	14421
5342	0728	8/12	5	13.66	38.46	37.06	10.82	3.64	1.26	10689	
	C32			Dry	44.54	42.92	12.54	4.22	1.46	12379	14462

[a] Analyses having the same file number are for the same mine. Attention is called to the fact that much greater dependence can be placed on these analyses where there are at least three for a given mine than where only one is available.

TABLE 42—*Concluded*

Laboratory No.	File No.[a]	Date	Coal Bed	Proximate Analysis of Coal 1st: "As rec'd," with total moisture 2nd: "Dry" or moisture free				Sulphur	CO_2	B. t. u.	Unit Coal
				Moisture	Volatile Matter	Fixed Carbon	Ash				
5343	0728	8/12	5	14.53	37.46	38.35	9.66	3.18	1.60	10804	
	C32			Dry	43.83	44.87	11.30	3.72	1.87	12641	14525
5344	0728	8/12	5	15.80	35.84	37.67	10.69	3.00	1.79	10460	
	C32			Dry	42.56	44.74	12.70	3.57	2.12	12423	14520
12436	0814	4/21	5	15.88	33.96	38.75	11.41	4.38	.92	10330	
				Dry	40.37	46.07	13.56	5.21	1.10	12280	14569
12437	0814	4/21	5	16.68	35.46	37.90	9.96	3.82	.61	10464	
				Dry	42.56	45.49	11.95	4.58	.74	12559	14579
12438	0814	4/21	5	14.53	35.68	38.23	11.56	3.45	1.00	10608	
				Dry	41.74	44.73	13.53	4.04	1.17	12411	14679
1404	0832	4/08	5	15.09	35.39	38.89	10.63	3.21	....	10573	
				Dry	41.68	45.80	12.52	3.79	....	12450	14447
5283	1116	8/12	5	15.18	37.17	35.17	12.48	3.45	1.70	10201	
	C31			Dry	43.82	41.45	14.73	4.07	2.00	12026	14441
5284	1116	8/12	5	16.94	35.68	37.15	10.23	2.98	1.31	10314	
	C31			Dry	42.95	44.73	12.32	3.59	1.57	12418	14446
5285	1116	8/12	5	18.42	34.98	37.66	8.94	2.33	.86	10270	
	C31			Dry	42.88	46.15	10.97	2.85	1.06	12587	14371
5296	1116	8/12	5	16.82	37.28	33.45	12.45	2.84	1.69	10580	
	C31			Dry	44.81	40.23	14.96	3.42	2.02	12038	14479
5298	1116	8/12	5	16.52	37.17	36.54	9.77	3.91	.81	10394	
	C31			Dry	44.52	43.78	11.70	4.69	.97	12451	14409
5341	1116	8/12	5	17.37	35.71	37.86	9.06	2.34	1.14	10420	
	C31			Dry	43.22	45.82	10.96	2.83	1.38	12610	14398
1856	1217a	9/08	5	15.44	35.88	38.35	10.33	3.52	....	10711	
				Dry	42.42	45.36	12.22	4.17	....	12666	14673
4387	1220	8/11	5	12.03	36.30	39.67	12.00	3.35	.72	10779	
				Dry	41.27	45.08	13.65	3.81	.82	12254	14652
4388	1220	8/11	5	14.04	36.14	39.28	10.54	3.46	.56	10721	
				Dry	42.04	45.69	12.27	4.02	.65	12472	14627
2651	1220a	8/09	5	14.35	34.48	36.98	14.19	4.44	....	10324	
				Dry	40.25	43.18	16.57	5.19	....	12053	14771

[a] Analyses having the same file number are for the same mine. Attention is called to the fact that much greater dependence can be placed on these analyses where there are at least three for a given mine than where only one is available.

MINES AND MINING METHODS

The larger mines in this area are usually provided with modern equipment and conveniences but the smaller shipping mines and practically all of the non-shipping mines employ primitive methods in mining the coal. The coal is worked by shafts in all but three of the commercial mines, and these drift in on the outcrop of the bed. The room and pillar method, or a modification of this plan, is followed in practically all of the mines. Machines for undercutting the coal are used in only a few of the larger mines, the coal generally being shot from the solid. Electric motors are

used for the main haulage in several of the larger mines, and the tail rope is used in a few others, but in the larger number of the mines all of the haulage is done by mules. In a few mines compressed air is used for working the drills and electricity is provided for lighting. The deeper mines are usually dry, but the more shallow ones are sometimes troubled with water seeping in from the roof. Generally, neither the necessary sprinkling nor pumping entails much expense. In the greater number of the mines few of the pillars are ever taken out, and at none of them is the coal washed before it is put on the market.

Nineteen shipping mines were operated in the Avon and Canton quadrangles during the year 1920, and more than 60 local mines were worked, generally by drifts or by stripping, during a small part of the year. The 1920 output of individual shipping mines in the area ranged from 4,826 to 238,400 tons, and of the non-shipping mines from 12 to 30,270 tons. In Table 43 is given a list of the commercial mines in the Avon and Canton quadrangles, and the location, depth to the top of the coal, and the thickness of the coal for each mine.

TABLE 43.—*List of shipping mines in and near the Canton and Avon quadrangles*

Name of Company	No. or Name of mine	Location ¼	Location ¼	Location sec.	T.N.	R.E.	Surface elevation	Depth to No. 5 coal	Alt. of top of coal	No. of coal	Thickness	Production 1919-1920
								Feet			*Ft. In.*	
Alden Coal Co.	No. 5	Cen.	N. ½	2	8	4	745	185	560	5	4 4	4,826
Alden Coal Co.	No. 6	NW	SW	27	8	4	762	190	572	5	4 3	115,105
Alden Coal Co.	No. 8	Cen.	SE	3	8	4	680±	70	610±	5	4 0	143,979
Big Creek Coals, Inc.	No. 2	SE	SW	16	6	4	...	drift	578	5	5 0	238,400
Big Creek Coals, Inc.	No. 4	NE	SE	22	6	4	637?	82	555?	5	5 6	158,390
Big Six Coal Co.	Big Six	NE	NW	31	8	3	...	drift	635±	5	4 0	....
Binzel Coal Co.	No. 1 (Binzel)	NW	SE	4	8	4	660±	41	620±	5	4 8	36,953
Canton Coal Co.	No. 1	NW	SW	34	8	4	740	180	560	5	4 1	154,973
Coal Creek Mining Co.	Parrville	NW	SW	30	8	3	...	drift	638	5	4 0	24,035
Cripple Creek Coal Co.	No. 1	SW	SW	24	6	3	...	drift	...	5	4 8	200,338
Cripple Creek Coal Co.	No. 2	SW	SW	24	6	3	...	drift	...	5	.. ..	
Eagle Mining Co.	Eagle	SE	SE	32	7	4	683	103	580	5	4 10	91,021
Genuine Norris Coal Mining Co.	Genuine Norris	SE	SE	34	8	4	735	180	555	5	4 1	....
Maplewood Coal Co.	No. 1	SE	NW	11	8	4	720	122	598	5	4 2	77,503
Maplewood Colliery Co.	No. 2	NW	SE	15	8	4	760	146	614	5	4 2	60,250
Middleton Coal Co.	Middleton	NE	SW	33	7	4	660	60	500	5	4 8	35,957
Monmouth Coal Co.	No. 1	NW	NW	11	7	4	705±	142	563±	5	4 6	136,304
National Coal Mining Co.	National	SE	SW	5	8	4	710	105	605	5	4 0	155,551
Rawalt Coal Co.	Rawalt	NE	NE	36	7	4	655	76	579	5	4 8	20,667
Shuler and Long	Parrville	NW	NW	31	8	3	...	...	...	..	.. ..	7,021
Silver Creek Colliery Co.	No. 1	SW	SE	4	8	4	675	41	634	5	4 0	186,798
Simmons Coal Co.	Simmons	SW	SW	14	7	4	682	121	561	5	4 6	88,216
Spoon River Colliery Co.	Ellisville: No. 1	NE	SW	28	8	2	540	34 (No.1)	06(No.1)	1	4 6	78,405
Star Coal Co.	Fiatt: No. 1	NW	SW	28	7	3	687	56	631	5	4 10	41,721
Star Coal Co.	No. 3	NW	SE	20	6	3	659	26	633	5	4 11	64,449
												2,120,862

Shale and Clay

Pennsylvanian shale and Pleistocene clay suitable for the manufacture of common brick and tile are found in nearly all parts of the Avon and Canton quadrangles, and both have been utilized in this area.

PENNSYLVANIAN SHALES

The shales outcropping in this region are of Pennsylvanian age, and on account of the abundance of this material exposed at the surface, none is sufficiently valuable to justify underground working, their use being confined to the area of outcrop of the beds where the shale can be dug from open pits. The most important shale horizons that are available over a considerable part of the area are (1) the shale overlying the Colchester (No. 2) coal, and (2) the Canton shale member overlying the limestone above the Springfield (No. 5) coal.

At a few places in the Avon quadrangle a lower shale lying between the Colchester (No. 2) and the Rock Island (No. 1) coals is favorably exposed and is of suitable quality for the manufacture of common clay products, as north of Avon shown in figure 42. The shale overlying the

Fig. 42. Shale exposed in the clay pit of the Avon Milling and Manufacturing Company, a quarter of a mile north of Avon

Colchester coal is exposed in a few places near the west side of the Canton quadrangle and in numerous places in the Avon, but it has never been utilized on an extensive scale. In connection with the mining of the Avon coal at Prairie City some years ago, this overlying shale was also taken out and used for the manufacture of brick and tile.

The Canton shale is the most valuable and generally accessible shale in the Canton quadrangles. It outcrops under thin cover at many places in the vicinity of Canton with a thickness of 15 to 30 feet, and is exploited by a number of clay working companies. This shale is gray and slightly sandy. It has good plasticity so it can be moulded by the stiff mud process, and does not shrink much in drying and burning. It permits a considerable range in temperature between initial fusion and vitrification, and is suitable for the manufacture of paving brick as well as the more common grades of brick and tile.

The shale bed underlying No. 7 coal, and also that below the Lonsdale limestone, are each of good thickness, and appear to be of fair quality. However, these shales are present over such a limited area, in the northeast part of the Canton quadrangles, and they are exposed so far from any town, that they at present are of little value.

PLEISTOCENE CLAYS

Available clays of Pleistocene age suitable for manufacture of common brick and tile comprise glacial drift, recent alluvium, and loess. Of this a small thickness of glacial till is used in one locality, but the loess which is widely distributed at the surface is more frequently utilized. The recent alluvium is not of great importance as a source of clay, being limited in distribution and commonly mixed with an objectionable amount of sand and gravel, and is subject to overflow during each year.

CLAY-WORKING PLANTS

The West Canton Paving Brick Company operates a large plant about one and one-half miles west of Canton. Paving and building brick, hollow block and drain tile are made of shale, from the Canton shale member, mixed with a small amount of loess, a vertical thickness of about 25 feet of shale and 4 to 6 feet of loess being worked. The yearly output is about 3 million building brick and 1 million paving brick, largely marketed in the city of Canton. Drain tile is also manufactured in such quantity as the local demand requires.

Heckard and Sons, in the west part of Canton, also use without stripping a thickness of about 17 feet of the Canton shale with about 3 feet of overlying loess, in the manufacture of paving, building, and sidewalk brick. An aggregate of about 6,000,000 brick per year are usually marketed, the proportion of different kinds depending on the demand. A considerable part of their production goes to the local market, but large quantities are also shipped to Peoria and Chicago.

For several years George B. Roller has operated a brick yard in the west part of Canton, manufacturing paving and common grades of building

brick. The raw material used is the Canton shale with no addition of loess or other clay.

The Avon Milling and Manufacturing Company, which is the only maker of clay products in the Avon quadrangles, has a pit about a quarter of a mile northwest of Avon (fig. 42). Common building brick, fire brick, and drain tile are manufactured from a mixture of shale, till, and loess. The face of the pit shows about 20 feet of shale, and 3 feet each of the till and the loess which is used in the proportions in the bank. The shale is in the Pottsville formation about 12 feet below the Colchester (No. 2) coal.

Sand and Gravel

Sand suitable for plaster and cement occurs in abundance in the dune-like hills bordering the east side of Spoon River near the northwest corner of the Canton quadrangles and south of London Mills in the Avon, and in the beds of all of the larger streams. Pleistocene gravel overlying Illinoian till is exposed in several places in the banks of the larger streams in this region, and also occurs in many places along the channels of the larger streams. The greater part of the sand and gravel used in the area is taken from the beds of Spoon River, near London Mills and Ellisville; Big Creek, near Canton; Put Creek, near Cuba; Littlers Creek, near Farmington; Cedar Creek, near Avon and St. Augustine; and Shaw Creek, near Marietta.

Building Stone

Good building stone is not abundant in the quadrangles. The limestone bed equivalent to that worked in the Lonsdale quarries farther east, in Peoria County, has been quarried about 2½ miles east of Farmington to supply local trade. It consists of two ledges of hard gray limestone, respectively 4 and 5 feet in thickness, separated by about 7 feet of calcareous shale. This limestone is present over a few square miles south of Farmington in the northeast quarter of the Canton quadrangles, but is not exposed within the area.

Sandstone suitable for foundation work and rough masonry has been quarried from two or three horizons of the Pottsville formation in different places in the Avon quadrangles. In the vicinity of Marietta station, a sandstone belonging not far below the Rock Island coal was formerly quarried on a commercial scale, a thickness of 12 to 20 feet being worked. The layers are ½ to 2½ feet thick and have furnished considerable dimension stone and other stone for bridge abutments and foundations. In the northeast quarter of sec. 25, T. 9 N., R. 1 W., a sandstone occurring a few feet below the Rock Island coal has been quarried in a few places to supply rough stone to the local trade. Another sandstone ledge 10 to 12 feet thick, a short distance above the Rock Island coal, was formerly extensively quarried in the NE. ¼ sec. 26, T. 9 N., R. 1 W. In several other places in the Avon

quadrangles sandstones of Pottsville age have been quarried in a small way for local purposes, but these would not generally furnish durable building stones. At present there are no active quarries in the area.

Soils

The wealth of the region embracing the Avon and Canton quadrangles depends primarily upon agriculture and hence the soil is its greatest natural resource. The soils of the quadrangles may be divided into four distinct types: 1, alluvial, 2, glacial till, 3, sandy, and 4, loess. These types, in places, more or less intergrade. These soils, like all others, have been formed by geologic processes to which are due to a large extent their texture, their physical and chemical composition, and their fertility. The character of the soil at any place depends upon the character of the rocks from which it was derived, and on the conditions and forces by which it has since been affected.

ALLUVIAL SOILS

The alluvial soils in this region occur over the flood plains of the larger streams and aggregate many square miles in extent. They are usually composed of clay and in most places are colored dark with organic matter. A considerable portion of the area of alluvial soils is subject to overflows which each year make additional contributions to the surface of this deposit. The flood plain areas have been largely cleared of the forests that originally covered them and, where properly drained, are second to none in fertility and constancy of productiveness.

GLACIAL TILL

Soils developed directly upon glacial till are in this region confined mostly to the slopes that are so steep that the loess has been removed by erosion, or has never been permitted to accumulate upon them. These soils consist mainly of clay with more or less sand and gravel. Owing to their position on the slopes they have been subjected to strong leaching and are thus low in humus and other more soluble plant foods, and are not generally highly productive.

SANDY SOIL

Sandy soil occurs over a few square miles on the east side of Spoon River above and below London Mills. It is granular, thin, and porous. It rapidly loses its moisture by evaporation, and suffers serious downward leaching of its soluble constituents, and, except in wet seasons, is not very productive.

LOESS SOILS

A mantle of loess generally covers the till and forms the surface material over the greater portion of the uplands to a depth of 10 to 15 or more feet.

It is yellowish brown to grey, except near the surface where it is colored dark with humus and organic matter. The constitutent particles of loess were originally derived from the till and thus they consist of diverse materials brought from widely separated areas and contain all the essential ingredients of an unusually fertile soil.

Its physical characters are also conducive to a good soil. Its constituent particles are so fine as to give it good power of resisting drought and prevent the rapid leaching of its plant food, while at the same time it is sufficiently porous to permit good under drainage. Where the slopes are not so steep as to suffer serious erosion, this soil produces excellent yields of corn, wheat, oats, and grasses, and is also favorable for the growth of apples, berries, and other fruits.

Water Resources

General Considerations

The water present in the soil and rocks below the surface is known as ground water, the source of which is rainfall. The average rainfall in this region is approximately 40 inches. When rain water sinks into the ground it eventually reaches a depth below which the pores of the soil and rocks are filled with water. The upper surface of this zone of saturation is known as the ground water level, or water-table. The water-table is not a plain, as the surface of the water of a pond, but it is lower in the vicinity of streams, and in areas where the surface materials are porous, than over uplands, and where the surface materials are more impervious.

The depth of the water-table in any region is not constant but depends primarily upon the variation in the amount of precipitation, and upon the nature of the rock or soil. The upper portion of the ground water is continually moving laterally and downward toward the permanent streams, at a rate varying with the nature of the soil or rocks. During periods of drought the water moving towards the streams is not replaced by rain water and hence, as the supply of ground water is diminished, the water-table is lowered. This general action is aided by evaporation at the surface and may continue until temporary streams and wells become dry. In order to furnish a permanent water supply, a well must be dug below the level to which the water-table falls in dry seasons.

The depth of the water-table is also affected by the nature of the rock or soil. Fine-grained, closely compacted material affords little pore space for the water, and hence furnishes less favorable conditions for the downward percolation of the water than do the coarser-grained soils and rocks. In the more impervious material, as clay, the water-table is usually nearer the surface than in more porous beds of sand and gravel. Among other factors affecting the height of the water-table are evaporation, temperature, and atmospheric pressure.

In addition to the periodic variation in the level of the water-table, there has been in recent years a permanent lowering of this level in Illinois, largely as a result of increased run-off due to deforestation and drainage, and to increased consumption of water with the increase of population and industries.

The configuration of the water-table corresponds in a general way to the topography of the surface. Gravity tends to cause it to assume a uniform level, but is opposed by capillary attraction which acts between the water particles and the grains of the material in which the water occurs. Capillary action is strongest in the fine-grained, more impervious material, and hence in fine-grained soils or rocks the water-table is more irregular than in regions of more porous beds of gravel, sand, or sandstone. On hill sides the gradient of the water-table is more gentle than the slope of the surface, and it is also more gentle where the surface is underlain by porous rocks than where the material is impervious clay. The depth to water is usually less on low lands than on the tops of the hills.

WATER-BEARING STRATA

All rocks and soils contain more or less water, but many of them do not hold it in appreciable amounts, nor do they part with it readily, and hence are not capable of furnishing a permanent and abundant water supply. The power of a rock to contain water depends upon its porosity, and this in turn depends largely upon the size and shape of its constituent particles; the larger and rounder these particles are the less closely do they interlock and hence the larger the pores or spaces between them that may contain water. As a consequence beds of gravel, sand, or sandstone contain the largest amounts of water, and such porous material permits the most ready movement of water through it, so that when water is drawn out of wells in such material, it quickly flows in again. For these reasons beds of gravel, sand and sandstone furnish much stronger water supplies than beds of clay, glacial till, or shale.

WATER SUPPLIES

STREAMS

Spoon River and its tributary Cedar Creek furnish an abundant and permanent supply of surface water to the regions through which they flow, and several of the other creeks in the area have a permanent flow in years of ordinary rainfall. Away from the streams shallow wells are the great source of water for farm use in the area. Most of the wells are dug in the Pleistocene materials, but a few obtain a water supply from deeper hard rock sources. A few large springs issue from a bed of sand or gravel beneath the drift and have a perennial flow which furnishes an excellent water supply.

SHALLOW WELLS

Several of the shallow wells of the area derive their water from the base of the loess which over the uplands often furnishes a good supply for farm use at a depth of 10 to 15 feet. The chief source of water in the shallow wells is a bed of sand or gravel lying within or immediately below the Illinoian till at depths ranging from 15 to 40 feet, commonly less than 25 feet. These sands and gravels associated with the drift usually yield an abundance of excellent water, the supply of which does not fluctuate with the seasonal rainfall so much as that of the wells obtaining water from the loess or from glacial drift. Drift or boulder clay like other clays contains little pore space and hence does not hold much water nor does it allow a ready percolation of water through it and so is a poor source of water supply.

WELLS IN ROCK

Many of the wells in the quadrangles pass through the Pleistocene materials into the Pennsylvanian rocks to a variable depth of 50 to 300 feet. The water in these wells does not appear to come from a common and continuous water-bearing bed, nor is the supply notably stronger than that of the wells obtaining water from sand or gravel in the glacial till.

That the water-bearing beds in the McLeansboro and Carbondale formations are not continuous in this region is shown by the fact that several of the wells which penetrate the Pennsylvanian rocks to a considerable depth do not obtain a strong water supply, and also by the coal shafts in the area. There are 22 coal shafts in the quadrangles, ranging in depth from 35 to 175 feet, none of which encountered a strong aquifer, nor does water find its way into any of the mines in sufficient quantity to cause serious trouble.

The city of Canton obtains its water from two wells put down to the St. Peter sandstone which is reached at about 1,445 to 1,475 feet. The Parlin and Orendorff Plow Co. in Canton also has put down a deep well to this formation. The town of Cuba has recently put in a deep well water supply from this sandstone which was reached at a depth of 1,470 feet. The water supply for the city of Bushnell is also obtained from the St. Peter sandstone at a depth of 1,351 feet. The water supply from this sandstone is unfailing, and the water is not so highly mineralized in this region as it is farther south in the state. A flowing well near New Philadelphia obtains water from the Trenton limestone which was reached at a depth of 831 feet.

Oil and Gas

THE HOING SAND

In the Colmar-Plymouth oil field the producing stratum is a sandstone, known as the Hoing sand, which is locally present immediately below the

Silurian limestone and above the Maquoketa shale in western Illinois. Sandstone is not known at this horizon in any other portion of the Mississippi Valley, and in this region it is not a persistent bed but occurs in separate areas, the general direction and extent of which have not yet been determined. This sand was probably derived from the deeply weathered residual material that was developed on the surface of the Maquoketa shale during the long period of land conditions that prevailed in this region between the end of the Maquoketa and the beginning of Niagaran time. This residual mantle was worked over and the sand sorted out and deposited in local depressions by the Niagaran sea when it first advanced over the region. This sandstone appears never to have been laid down over an extensive area, for many of the wells pass from the Niagaran limestone directly into the Maquoketa shale. In some places it may have been removed by erosion during the post-Niagaran-pre-Hamilton land interval. During this erosion period the Silurian strata were in some places entirely removed, so that the Devonian limestone was deposited in erosional unconformity upon the Maquoketa shale.

OTHER POSSIBLE OIL-BEARING HORIZONS

Since the Niagaran dolomite is productive of gas in the Pittsfield (Pike County) field; and since the "Trenton" formation yields oil in commercial quantities in the Waterloo (Monroe County) field, tests on the better structure in the Avon-Canton area might well be continued into these horizons. Their approximate depths may be learned from the columnar section on the map, Plate I, and from the detailed well sections in an earlier part of this report.

RELATION OF ACCUMULATION TO FOLDS IN THE OIL-BEARING BED

In most of the productive fields of Illinois, as in Lawrence and Crawford counties, the oil occurs in the upper parts of anticlines or domes, or in terraces on the sides of the folds. The productive oil fields of Illinois are surrounded by a barren area in which the wells tap salt water. This is strong evidence that the water is an important factor in determining where the oil will accumulate in the sand stratum after it has been more or less folded. When the sand is practically saturated with water the oil generally occurs near the crest of the anticlines. When the sand is only partially saturated with water the oil is found farther down the sides of the folds, and the crests may be dry. If no water is present, the oil may occur in the troughs or synclines, and the anticlines may be barren.

In western Illinois the strata have a gentle eastward dip and the structural features consist of small folds, domes, or terraces which have been developed as small irregularities or interruptions in the general eastward slope, the crests of many of the larger anticlines or domes being only 20 or 30 to 50 feet high. The oil-bearing sandstone is present only in disconnected

patches or separate lenses as is shown by the fact that the oil and water in the sandstone occur in different places at such different elevations as to preclude the possibility of the lateral connection of the strata between them. Under these conditions the accumulation may progress in each lens independently, and the degree of saturation by oil and water determine whether the accumulation will take place at the top of the folds or in the terraces lower down or in the troughs or lowest parts of the depressions.

LOCALITIES ALREADY TESTED

Although deep water wells do not test the strata for oil and gas accumulation as effectively as wells drilled for that specific purpose, the evidence they give is nevertheless well worth noting. In Canton three deep wells put down for a water supply penetrated to a depth of 600 to 700 feet or more below the horizon of the Hoing sand without finding any oil. At Cuba a similar well, drilled to the St. Peter sandstone, encountered no oil or gas; the Trenton was reached at a depth of 1,170 feet. Deep wells have also been drilled at Bushnell and at Avon, but no oil or gas was encountered. The city of Farmington drilled a 1,700-foot well in 1917 which reached the base of the Niagaran at a depth of 1,075 feet and the top of the "Trenton" at 1,235. On the Merrill farm in SE. cor. NW. 1/4 SE. 1/4 sec. 19, T. 8 N., R. 1 E., a 612-foot well, drilled probably for water, reached the top of the Niagaran lime at a depth of 580 feet. In a deep well on the J. E. Harris farm in the SW. 1/4 sec. 31, T. 6 N., R. 1 E., about three miles south of the Avon quadrangles, a showing of oil was reported in the lower part of the Niagaran limestone at depths of 610 and 635 feet, respectively, the latter of which is only a few feet above the horizon of the Hoing sand. A dry oil test was completed in 1917 by the Ohio Oil Company on the Gannett farm in the NW. 1/4 SE. 1/4 sec. 29, T. 8 N., R. 3 E., but a good log is not available; this test was structurally very well located. An oil test drilled in 1916 on the J. C. Morgan farm in sec. 24, T. 6 N., R. 1 E., was said to have penetrated the horizon of the Hoing sand but the samples submitted proved to be dolomite rather than sand; either the Hoing sand is absent at this location or else the well was not deep enough to reach its horizon. Another dry oil test drilled in 1917 on the Schafer farm in sec. 26, T. 6 N., R. 1 E., was just in the Niagaran at a depth of 588 and therefore did not reach the Hoing sand if that depth was the full depth of the well. Information as to the character of the structure on which the Morgan and Schafer tests were located is not available as they lie on the unworked area just south of the Avon quadrangles.

GAS IN GLACIAL DRIFT

Small quantities of gas have been reported from porous beds in the glacial drift at several places in this region. In a water well near the northeast corner of sec. 22, T. 7 N., R. 2 E., gas rises in bubbles through

the water every few minutes in such quantity that it can be ignited with a match. In a well drilled on the farm of J. E. Harris, the log of which has been given on a previous page, gas was encountered in beds of sand and gravel at the depth of 58 and 72 feet, respectively, in such quantity as to interfere with the lights in the drilling rig. Two years after this drilling was made gas continued to rise through the water of this well in such quantity that it could be readily ignited at the mouth of the well. Small quantities of gas have been reported in a number of other shallow water wells in this region. In all of these cases the gas was doubtless derived from the decomposition of organic matter that was buried in the glacial drift, and it can not be expected to occur in such quantity as to be commercially important. It has no necessary connection with oil or gas accumulations in the deeper rock strata, nor is its presence in the beds of sand and gravel of Pleistocene age any indication that oil or gas is present in the deeper hard rock strata of the region.

RECOMMENDATIONS

In the Colmar region farther west the oil is sometimes found in the upper part of the anticlines or domes, and sometimes in terraces on their sides, and sometimes the oil sand is wanting where the structure appears favorable. Consequently, any recommendations for test borings for oil in the Avon and Canton area, based on the usual structure features, must be recognized as carrying an unusual amount of uncertainty. However, since it is not possible to tell before borings are made whether the Hoing sand is present or to what extent it is saturated with water in any particular locality, if test borings are to be made, it would seem wise to proceed first on the usual assumption that the rocks will be thoroughly saturated with water, and to test first the places where the structure is most favorable, as the highest parts of the anticlines and domes.

From the structure map it will be seen that a broad dome is present a few miles northwest of Fairview, the highest point of which is in the NE. ¼ sec. 29, and the SE. ¼ sec. 20, T. 8 N., R. 3 E. The Ohio Oil Company's test on the Gannett farm was dry, in the SE. ¼ sec. 29. A low anticline continues eastward from this dome passing near the town of Farmington. South of this area a smaller dome occurs west of Fiatt and is continued towards the southeast in a rather pronounced arch to near the southeast corner of the Canton quadrangles. In the northwest quarter of the Avon quadrangles, a low anticline is present near the elbow of Swan Creek, in sections 14 and 23, T. 8 N., R. 1 W. From this place it trends towards the southeast, becoming most prominent about one mile north of Babylon in sec. 11, T. 7 N., R. 1 E., where the structure appears rather favorable for the accumulation of oil. In a few places in the southeast quarter of the Avon quadrangles irregularities of structure of small extent are present,

but no place particularly favorable for the accumulation of oil and gas could be mentioned.

If the Hoing sand is found in one or more of these places, and no oil or water is encountered, tests might be made farther down the slope to find out whether the absence of oil in the higher parts was due to the absence of water farther down the dip.

FIG. 43. Index map showing the locations of clay samples and the approximate position of the outcrop of the Cheltenham clay.

FURTHER INVESTIGATIONS OF ILLINOIS FIRE CLAYS

By C. W. Parmelee and C. R. Schroyer

OUTLINE

ILLUSTRATIONS

TABLE

FOREWORD

Very early during the participation of the United States in the World War, the importance of a better knowledge of the extent and character of the refractory clay resources of Illinois was recognized. The cessation of importations of certain types of such clays which had previously been brought from enemy countries had made it imperative that domestic clays of suitable sorts should be discovered, if possible. Further, the general disturbance of the economic life by the war had greatly increased the costs and difficulties of transportation and emphasized the necessity for a more comprehensive survey of these clays than had yet been undertaken by the State.

Consequently, Mr. C. R. Schroyer of the Survey was assigned the duty of visiting deposits, gathering the samples, and making the necessary studies of the geological conditions. Prof. Cullen W. Parmelee of the Department of Ceramic Engineering of the University of Illinois was given charge of the testing of the clays which was done in the laboratories of the department mentioned.

All known clay deposits which gave promise of being of refractory value were examined and areas which had not been previously investigated were carefully searched. Fig. 43 shows the locations of all deposits sampled.

The work was well advanced when the armistice was signed, but the cessation of hostilities was not considered a justification for termination of the investigation since it was recognized that the results would have very considerable permanent economic value. Therefore, the work has been somewhat extended and a few clays of a non-refractory type have been included since the samples were already at hand.

Since the clays of the embayment area in the southern counties of the state have proved to be of unusual interest, it was thought desirable to study their relation to the very important deposits of the embayment area in western Tennessee and Kentucky. The authors of the bulletin, together with Dr. H. Ries of the U. S. Geological Survey, visited the deposits of western Kentucky and, accompanied by Mr. Wilbur A. Nelson, State Geologist of Tennessee, visited those of the latter state.

A visit was also made to the deposits at Lutesville and Glen Allen, Missouri, in order to determine what relation, if any, existed between that area and clay deposits in the southern part of the state.

The authors therefore wish to express their appreciation of the assistance extended to them by the gentlemen named, as well as the many citizens of this State who have contributed in various ways to the successful prosecution of this work.

INTRODUCTION: A GENERAL DISCUSSION OF CLAYS

By C. W. Parmelee

The Classification of Clays

PURPOSE AND DIFFICULTIES

It is possible to classify clays in many ways; as for example, mode of origin, mineralogical character, physical properties, and uses, and several such classifications[1] have been published. The classification here presented is an attempt to correlate certain physical properties with uses.

Difficulties are experienced in such an attempt because of the incomplete state of our knowledge of clays and clay products. We still have much to learn about the properties of the unburned and the burned clays and their products.

Much information has been gathered through the agencies of the American Ceramic Society and other similar organizations, the various geological surveys, industrial laboratories, and research conducted at the various universities. Through cooperation of these various agencies, standard methods of testing are being devised and standard specifications prepared, but the task is a large one and is made particularly difficult because of our ignorance of much that is fundamental relating to the material.

One of the benefits which may be attributed to the recent war was the impetus given to the investigation of these problems. As consequences of this, not only has the knowledge of our clay resources been extended, but much has been learned about the requirements to be met by the raw materials and also the conditions which the finished product should satisfy. A better understanding of these conditions has brought about a notable improvement in the products.

Any economic classification of clays made at this time is to be regarded as only tentative, for the reason previously mentioned, namely, the incomplete state of our knowledge of the properties of the raw materials which gives them especial value in the manufacture of certain products. Further, in the consideration of such a classification it must be remembered that with the exception of certain products of the cruder sort, it is the practice to blend two or more clays which are commonly of quite different kinds, with a view to obtaining mixtures which may be formed into wares without too much difficulty or loss, and which will possess the desired properties. Therefore, in the following classification, an attempt has been made to indicate what may be called the primary uses or, in other words, those for which the clay is particularly adapted. This does not exclude clays from uses for purposes not specified. For example, a superior fire clay may be suited for the manufacture of common brick. Its primary usefulness, however, may be regarded as for firebrick since it will be most valuable manufactured into that product.

[1]Ries, H. Clays; their occurrence, properties and uses: p. 23, 1914.

A PROPOSED CLASSIFICATION[1]

The clays are classified for use according to the physical properties which give them especial value for specific purposes.

I. CLAYS BURNING WHITE OR CREAM COLORED, NOT CALCAREOUS

A. OPEN BURNING CLAYS, i. e., still distinctly porous at cone 15

1. Low strength, e. g., residual kaolins such as those from North Carolina
2. Medium and high strength, e. g., secondary kaolins such as those from Florida and Georgia

Clays of the open burning type are of value in the manufacture of pottery because of their good color or because of the good strength and good color. These clays are frequently of a good or high degree of refractoriness. If of a good color, they may be used for special refractories such as pots for melting optical glass; or the color may be of secondary importance and the clays may be valued for their refractoriness only

B. CLAYS BURNING DENSE, i. e., become nearly or completely non-porous between cones 10 and 15

a. Non-refractory clays:

3. Good color, medium to high strength, medium shrinkage. Uses: Pottery, including certain whiteware, porcelains, stoneware
4. Poor color, medium to high strength, medium shrinkage. Uses: Stoneware, terra cotta, abrasive wheels, zinc retorts, face brick, saggars

b. Refractory clays:

5. Good color, medium to high strength, medium shrinkage. Uses: Refractories, especially for glass, if they do not overburn seriously for 5 cones higher. Also uses stated in 3

C. DENSE BURNING CLAYS, i. e., become nearly or completely non-porous between cones 5 and 10 and do not overburn seriously at 5 cones higher than the temperature at which minimum porosity is reached

a. Non-refractory clays:

6. Good color, medium to high strength, medium shrinkage; usually reach minimum porosity between cones 5 and 8. Type: Ball clays. Uses: Pottery, whiteware, porcelain, and stoneware
7. Poor color, medium to high strength, medium shrinkage. Uses: Stoneware, terra cotta, abrasive wheels, zinc retorts, face brick, saggars

b. Refractory clays:

8. Non-porous or practically so at cone 5: do not seriously overburn for 12 cones higher; highly refractory; softening point at cone 31 or higher; bonding strength minimum 325 pounds per square inch. Use: Graphite cucibles for melting brass.[2]
9. Non-porous at about 1275° C. (cone 8), not overfiring at 1400° C. or higher. Strength and softening point as above[2]. Use: Steel crucibles
10. Become dense at about 1275° C. (cone 8). Do not overburn below 1425° C. Bonding strength, 250 pounds per square inch or higher. Softening point, cone 29 or higher[2]. Use: glass pots

---

[1]This classification relates only to the uses of clays for burned products and consequently no consideration is given to its uses as filler for paper or cloth, as a pigment, etc. For a definition of the terms "refractory" and "non-refractory" as used in this classification and throughout the report, see page 281. For the terms "medium" and "high strength," see page 290 et seq.

[2]See page 284.

II. Buff Burning Clays

A. refractory clays

a. Open burning, i. e., having a porosity of 5 per cent or more at cone 15 or above:

Indurated—non-plastic or slightly plastic unless it has been weathered. Type: flint clay.

11. Normally aluminous; maximum alumina 40%. Use: Refractories
12. Highly aluminous; alumina exceeds 40%. Type: Diaspore clay. Uses: Refractories, abrasives

Plastic

13. Normally siliceous; maximum silica not exceeding 65%. Uses: Firebrick and other refractory wares, terra cotta, sanitary ware, glazed and enamelled brick (see specific requirements for these below)
14. Siliceous; having a silica content above 65%. Type: Many of the New Jersey fire clays. Uses: Firebrick and other refractories

b. Dense burning between cones 10 and 15, i. e., attaining a minimum porosity of 5% or less within that range:

15. Medium to high strength. Do not overburn for 5 cones higher than point of minimum porosity. Uses: Glass pots and other refractories; also used for firebrick, saggars and miscellaneous refractories, architectural terra cotta, sanitary ware, enamelled and face brick

c. Dense burning, i. e., attaining a porosity of 5% or less at cone 10 or lower:

16. See 8
17. See 9
18. See 10

These three classes, 16, 17 and 18, are used also for zinc retorts, firebrick, saggars, and miscellaneous refractories, architectural terra cotta, sanitary ware, enamelled and face brick

B. non-refractory clays

a. Open burning, i. e., do not attain a porosity of 5% or less at any cone lower than cone 10:

19. High or medium strength. Uses: Architectural terra cotta, stoneware, yellow ware, face brick, sanitary ware
20. Low strength. Use: Brick

b. Dense burning, i. e., attain a porosity of less than 5% at cones lower than 10:

21. High or medium strength. Uses: Architectural terra cotta, stoneware, abrasive wheels, sanitary ware, face brick, paving brick

III. Clays Burning Red, Brown, or Other Dark Colors

A. open burning clays, i. e., those that do not attain low porosity at any temperature short of actual fusion

22. Medium or high strength. Uses: Brick, drain tile, hollow blocks, flower pots, pencil clays, ballast
23. Low strength. Use: Brick

B. dense burning clays

a. Having a long vitrification range (5 cones):

24. High or medium strength. Uses: Conduits, sewer pipe, paving brick, floor tile or quarries, electrical porcelain, cooking ware, silo block, art ware, face brick, architectural terra cotta, roofing tile
25. Low strength. Uses: As dust body in the manufacture of electrical porcelain, floor tile, building brick

b. Having a short vitrification range:

26. High or medium strength. Uses: Building brick, face brick, hollow block, flower pots

c. Fusing at a low temperature, approximately cone 5, to form a glass:

27. Slip clays

IV. Clays Burning Dirty White, Cream White, or Yellowish White

28. Containing calcium or magnesium carbonate or both. Never reach very low porosity. Have a very short heat range. Use: Common brick

Types and Uses of Clays

In the "Clay Classification," references are made to certain types of clays which have been found adapted to special uses. In the following brief descriptions an endeavor is made to state the characteristics of such. However, the fact that a clay is designated a terra cotta clay or a sanitary ware clay, for example, does not necessarily mean that the clay constitutes a distinct type, and the attempt has been merely to describe the kind of material which is sought for the use indicated. As a matter of fact, for many purposes it is quite impossible to define the characteristics closely.

KAOLIN OR CHINA CLAY

The true kaolin is residual in its origin. It has a low degree of plasticity, low strength, low shrinkage both in drying and burning, and after purification by washing is refractory. The term kaolin is used in this country for the same type of material as that designated by the English potter as china clay, and kaolins are used for the same purposes as china clays. Since there would be an advantage in introducing a distinction between the terms, it has been proposed to restrict the term kaolin to the crude material and china clay to that which has been purified for the market.[1]

Kaolins do not always burn white. Some that are so badly stained that they are unsuited for use by the potter, may have considerable value if refractory. True kaolins have not been found in the State, nor is there much likelihood of such a discovery. The so-called kaolins of Union County are misnamed.

SECONDARY KAOLINS

These differ in origin from the true kaolins in that they have been transported from the place of origin by water and laid down in extensive beds. They are more plastic, stronger, and have higher shrinkages. They burn white, although not quite equalling the best residual kaolins. They are adapted to uses similar to those of the true kaolins.

[1]Mellor, J. W., A note on the nomenclature of clays: Trans. English Ceramic Soc. VIII, p. 23.

BALL CLAY

These are highly plastic, strong clays which burn cream white or a very light buff and vitrify between cones 5 and 10, so that they are non-absorbent. No ball clays have been located in Illinois, although the so-called kaolins of Union County have the characteristics of this type. It is possible that some of the stoneware clays of the State may be of a sufficiently good quality after washing to permit their use for some of the purposes for which ball clay is suitable. Ball clays are sedimentary in their origin. The drying shrinkage is ordinarily less than 10 per cent; the modulus of rupture as determined by the cross-breaking strength test varies between 200 and 500 pounds the square inch, with an average of 350 pounds; the tensile strength per square inch varies between 125 and 150 pounds; the total shrinkage at cone 10 varies between 16 and 20 per cent. The water of plasticity varies between 27 and 43 per cent with an average of 32.6 per cent.

REFRACTORY CLAYS

Clays are designated as refractory if they are capable of withstanding high temperatures without showing signs of fusion such as deformation, i. e., loss of shape, or softening to a fluid state.

Since all clays are able to withstand relatively high temperatures, and since no standard has yet been adopted, it becomes necessary to define more precisely what is meant by the term refractory clay. Purdy[1] and Bleininger[2] have suggested cone 26, and Ries[3] has named cone 31 as the boundary between the refractory and the semi-refractory clays with cone 27 as the lower limit for the latter clays. For purposes of this bulletin, all clays which fuse at cone 27 or higher are considered to be refractory and those which fuse at cone 33 or above are classified as highly refractory.

The term fireclay has come to be used in a broader sense than is connoted by mere refractoriness. It is now applied, at least in the middle west, to clays which have some of the characteristics of the true fireclays without regard to their ability to withstand very high temperatures. Commercially they have been divided into three classes which are known as No. 1, No. 2, and No. 3. The separation into these three grades has to a large extent been left to the convenience of the miner who wishes to make a distinction between materials but lacks the means for differentiating explicitly. Some attempt has been made to standardize these terms: for example, Bleininger[4] prescribes the lower limit of the softening temperature of No. 1 fireclay as

[1]Purdy, R. C., and DeWolf, F. W., Preliminary investigation of Illinois fire clays: Ill. State Geol. Survey Bull. 4, p. 149, 1907.

[2]Bleininger, A. V., The testing of clay refractories: U. S. Bureau of Standards Tech. Paper No. 7, p. 15, 1912.

[3]Ries, H., The clays and clay industry of New Jersey: New Jersey Geol. Survey, Final Rept. Vol. VI, p. 311, 1904.

[4]Bleininger, A. V., The testing of clay refractories: U. S. Bureau of Standards Tech. Paper No. 7, p. 44, 1912.

cone 32; and further, according to Purdy,[1] the time-temperature rate of vitrification is very slow so that it attains a low porosity only at a very high temperature, if at all.

The term No. 2 fireclay is peculiar to the middle west. Not infrequently it is used by a clay miner to designate a grade which is inferior to the best which he is mining. However, the term is most frequently employed to designate a clay which burns to a light color—a cream, buff, or light tan—and attains a low porosity at some temperature between cone 5 and cone 11. These limits have been arbitrarily set by the writer since, with the exception of some work done by Purdy[2] no attempt has been made to define the term with exactness. These clays are somewhat less refractory than the No. 1 grade and burn to a dense structure which makes them unsuited as the chief clay component for the manufacture of the best grade of firebrick. The fact that the term No. 2 fireclay in some cases connotes "second-grade" and the fact that use of this clay in the manufacture of this particular product is limited, should not be misunderstood and the class consequently undervalued, for amongst these No. 2 fireclays some of the most useful of the fireclays are found. The refractory clays of this class which have high strength are indispensable in the manufacture of crucibles, zinc retorts, and glass refractories, and those of good strength are necessary as the bonding agent for the No. 1 fireclays in the manufacture of the best grade firebrick.

According to Mr. Purdy[3] the No. 2 fireclays may fuse as low as cone 16 and may be as high as cone 26, which is the minimum refractoriness of a No. 1 fireclay. Bleininger[4] states that "There is no sharp distinction between the No. 1 and the No. 2 fireclays, and any lower limits that may be set must be, in the nature of the case, arbitrary." Further he states[5] that "cone 28 might be considered the limit below which a satisfactory bond clay should not soften." This is not incompatible with the experience of Mr. Purdy[6] since he found that the "fusion point [of the No. 1 clays] in the majority of cases does not exceed that of the so-called No. 2 fireclays."

It would seem from the above references that there is much confusion in the use of the term No. 2 fireclay. In the opinion of the writer, the term should be abandoned in technical literature and its use otherwise discouraged for two reasons: (1) it carries with it an implication of inferiority which is most unfortunate since many of the clays which may be grouped under this class are quite as valuable and indispensable as those which we call the No. 1 fireclays; and (2) it makes no distinction between the refractory clays

[1]Rolfe, C. W., Purdy, R. C., Talbot, A. N., and Baker, I. O., Paving brick and paving brick clays of Illinois. Ill. State Geol. Survey Bull. 9, p. 270, 1908.
[2]Ibid., p. 272.
[3]Purdy, R. C., and DeWolf, F. W., Preliminary investigations of Illinois fire clays: Ill. State Geol. Survey Bull. 4, p. 139, 1907.
[4]Bleininger, A. V., The testing of clay refractories: U. S. Bureau of Standards Tech. Paper No. 7, p. 45, 1912.
[5]Ibid., p. 45.
[6]Purdy, R. C., and DeWolf, F. W., Preliminary investigations of Illinois fire clays: Ill. State Geol. Survey Bull. 4, p. 139, 1907.

and those which are non-refractory. In other words, the term is used to include those clays which are not fireclays in the strict interpretation of the term. It seems to the writer to be more desirable to use a terminology such as proposed in the classification on pages 10 to 12.

The use of the term No. 3 fireclays seems to be equally unfortunate. These have been described by Purdy[1] as seldom having fusion points exceeding cones 16 and 17. He differentiates them from the No. 2 fireclays on the basis of the rate of temperature-porosity changes. Since the basis of the distinction is not refractoriness and the type clay is non-refractory, it would therefore be better to avoid the use of the word fireclay. There are refractory clays which have a rate of temperature-porosity change which would place them in this group. Because of other physical properties, they are adapted for use for specific purposes which gives them an especial value: for example, the crucible clays and those used for zinc retorts. It would seem a mistake to group this type indiscriminately with the non-refractory clays simply because of the rate of temperature-porosity change.

The method of studying clays by means of the temperature-porosity changes has been found to be exceedingly useful, although the scheme of classification which Mr. Purdy proposed as based upon the rate of these changes has been subject to criticism by later investigators.[2] Some of the difficulties encountered were anticipated by him in the statement "it is possible that broader limits will be determined when more and a larger variety of clays are tested." Beecher[3] in his study of Iowa clays attempted to use the proposed classification but found several marked irregularities. It is difficult to understand these with our present limited knowledge of the mineralogical and chemical constitution of clays. However, it points to the necessity for broader knowledge of these matters. As previously stated, the *method* of study has been widely adopted and has been very fruitful.

PLASTIC REFRACTORY BOND CLAYS

These clays are used in the manufacture of crucibles, glass pots, zinc retorts, and miscellaneous glass house refractories. They are used in mixtures with less plastic clays and with non-plastic materials. According to the investigations of A. V. Bleininger and his associates at the U. S. Bureau of Standards,[4,5] the requirements to be met by these clays are as follows:

---

[1]Rolfe, C. W., Purdy, R. C., Talbot, A. N., and Baker, I. O.: Paving brick and paving brick clays of Illinois: Ill. State Geol. Survey Bull. 9, p. 272, 1908.

[2]Bleininger, A. V., The testing of clay refractories: U. S. Bureau of Standards Tech. Paper No. 7, p. 44, 1912.

[3]Beecher, Milton F., Iowa State College Eng. Exp. Station Bull. 40, p. 88, 1915.

[4]Bleininger, A. V., Properties of American bond clays, etc.; U. S. Bureau of Standards, Tech. Paper No. 144, 1920.

[5]Bleininger, A. V., and Schurecht, H. G., Properties of some European plastic fire clays: U. S. Bureau of Standards Tech. Paper No. 79, 1916.

The siliceous clays and those for glass refractories should not soften below cone 30; for severe service the softening point should be above cone 31. In consideration of the clay having other desirable properties, some modification of this may be made; for example, a very well known foreign clay which formerly was widely used softened at about cone 28. The water of plasticity varies between 30 and 45 per cent; the linear drying shrinkage should lie between 6.5 and 10 per cent; the plasticity should be high; the strength as measured in terms of bonding power expressed as modulus of rupture, obtained by testing a mixture of equal parts of the clay and grog is 325 pounds per square inch for Class A, and 225 pounds per square inch for Class B. A classification[1] made according to the burning conduct is as follows:

1—Burn dense at about 1150° C. (2102° F.) and not overfired at 1400° C. (2552° F.). Especially suited for graphite crucibles for brass melting.

2—Burn dense at about 1275° C. (2327° F.) and do not overfire at 1400° C. (2552° F.) or higher. Suited for crucibles for steel and valuable for glass refractories if they do not overburn below 1425° C. (2597° F.).

3—Burn dense at 1425° C. (2597° F.) or higher. May overfire at 1450° C. (2647° F.) or above. Valuable for glass refractories.

4—Burn dense between 1150° C. (2102° F.) and 1300° C. (2372° F.) and have short heat range. Unsuited for refractory bond clay.

The above classification applies to clays burned at the rate of 20° C. (36° F.) per hour above 800° C. (1472° F.).

According to M. G. Babcock[2] the requirements of a zinc retort clay are: Considerable strength and bonding power; a linear shrinkage between 4 and 6.5 per cent; a porosity-temperature range from 10 per cent at 1150° C. (2102° F.) to about 5 per cent at 1250° C. (2282° F.); it should not overburn lower than 1400° C. (2552° F.); deformation point should not be below cone 30.

ARCHITECTURAL TERRA COTTA CLAYS

These are similar to the stoneware clays. They should be free from pyrites, concretions, soluble salts, gypsum, coaly forms of carbon, and other objectionable forms of foreign materials, because the clays are rarely washed before using. The presence of free silica in excess of 3 per cent in the form of grains which will not pass a 200 mesh sieve is considered objectionable by one firm of manufacturers. The red-burning clays are seldom used for this purpose since they are not as well-suited as are the light cream or light

[1]Bleininger, A. V., and Loomis, G. A., The properties of some American bond clays: Trans. of the American Ceramic Soc., Vol. 19, p. 606, 1917.

[2]Babcock, M. G., Refractories for the zinc industry: Jour. Am. Cer. Soc., Vol. 2, p. 81, 1919.

buff colors for the type of decoration ordinarily applied to this product. The clays should have a good plasticity and be strong, but those which are sticky or rubbery when in the plastic condition are avoided. Since the terra cotta bodies are compounded of mixtures of clays and grog (i.e., ground burned clay), the manufacturer may control the shrinkages very readily, but it is desirable that the shrinkages of the clays used should be low or medium. The clays should slake readily when wet with water, so that they may be brought to a uniformly plastic mass without delay. Usually two or more clays are used in the batch. One of these at least should burn dense at some temperature within the ordinary range, namely, between cones 1 and 6, and the minimum porosity should be 10 per cent or lower. The clay should have a sufficiently long heat range at the cone temperature of minimum porosity so that there will not be any danger of overburning in the commercial kiln. These dense burning clays should not warp or crack in the drying or burning process. The other clay used will be of the open burning type.

STONEWARE CLAYS

These are sedimentary clays which have good plasticity and strength, burn to a cream or light tan color, and reach a low porosity between cones 5 and 9. They should be free from substances which will give rise to the formation of soluble salts. It is desirable that the clays be free from concretions, pyrites, coaly forms of carbon, and other substances which may interfere with the use of the clay, although washing of the clay, which is frequently resorted to preparatory to use, will remove them. A comparison of the data regarding the stoneware clays used in different parts of the United States indicates that the physical properties are, on the average, as follows: The water of plasticity is from 18 to 37 per cent, though the usual amount is 35 per cent; the drying shrinkage varies between 5 and 13 per cent, and the average is about 8 per cent; the strength of the clay as measured by the crossbreaking test[1] varies between 125 and 400 pounds with the average at about 250 pounds per square inch; the tensile strength varies between 100 and 300 pounds with an average of 150 pounds; the minimum porosity attained during burning is between 5 and 10 per cent, which may be reached between cones 5 and 10; the average burning shrinkage is probably about 8 per cent.

SAGGAR CLAYS

Two types of clays are used in mixtures for the manufacture of these wares, namely, an open burning clay of good refractoriness, and a clay of lower refractoriness which will burn dense at a low temperature. It is desirable that both types should have good plasticity and good strength, although these properties may be the characteristics of only one of the clays used. It is important that the clays do not contain pyrites, concretionary

[1] I. e., modulus of rupture.

matter, or other foreign material which may cause damage to the wares placed in the saggars for burning. The shrinkages of the clays are not important since the mixtures contain a very considerable amount of grog and, moreover, small variations in size are of no moment. Unless the saggars are to be used at very high temperatures, it is not necessary to use high grade refractory clays. It is quite essential, however, that the clays should be suitable for use in mixtures which are subjected to heavy loads at high temperatures. Knowledge of the fundamentals of good saggar making is as yet in a rudimentary stage, and there is a great divergence in the practice of potters in the choice of materials and their proportions.

SANITARY WARE CLAYS

The clays used in the manufacture of such wares as bath tubs, wash trays, and sinks, are similar to those used in the manufacture of terra cotta.

PAVING BRICK CLAYS

The requirements to be met by these clays are good plasticity so that they may be formed as brick by the auger machine; little or no tendency to laminate; good strength; safe drying properties so that they will not warp or crack during that process; a low carbon and sulphur content so that they may be readily and safely oxidized during the burning process; little or no concretionary material; the color of the burned ware should be a good red in order to meet the usual requirements of the trade, although paving bricks are made also of clays burning to a light color; the minimum porosity should be approximately 5 per cent or less and this should be attained with a sufficiently wide heat range so that there will be no danger of overburning in the ordinary commercial kiln; the product must develop a sufficient degree of toughness to meet the usual tests; the linear drying shrinkage may vary considerably, but the ordinary maximum is 8 per cent and the average is 6 per cent; the water of plasticity of typical paving brick clays is 17 per cent.

FACE BRICK CLAYS

Clays of a great variety are used for this purpose and the requirements which must be met may be stated only in a general way. For the purpose of manufacturing by the plastic process, which is that most generally used, the clay must be of a sort which will flow readily through the die of the brick machine. No marked development of lamination should occur. The clay should have a fair or good strength in the dry condition. It should dry readily and safely without a tendency to warp or crack. The usual shrinkage is from 6 to 8 per cent, although it varies widely. The appearance of a scum, whitewash, or efflorescence of any kind at this or subsequent stages in the manufacture is objectionable. The clay should be practically free from minerals of a harmful kind, size, or quantity, as for example, calcium carbonate in its various forms, pyrites, and concretionary iron. The clays should burn hard and strong without warping, blistering, pitting, etc.

They should attain a low per cent of absorption at a temperature which is commercially practicable. This varies widely according to the type of material and may be said not to exceed cone 8 and usually lies below cone 1. The clays should have a sufficiently wide heat range to permit the necessary degree of vitrification without danger of overburning and the variations in color throughout the burn should be of a sort both as to shade and variety as to permit satisfactory grading.

Conservation of Clays

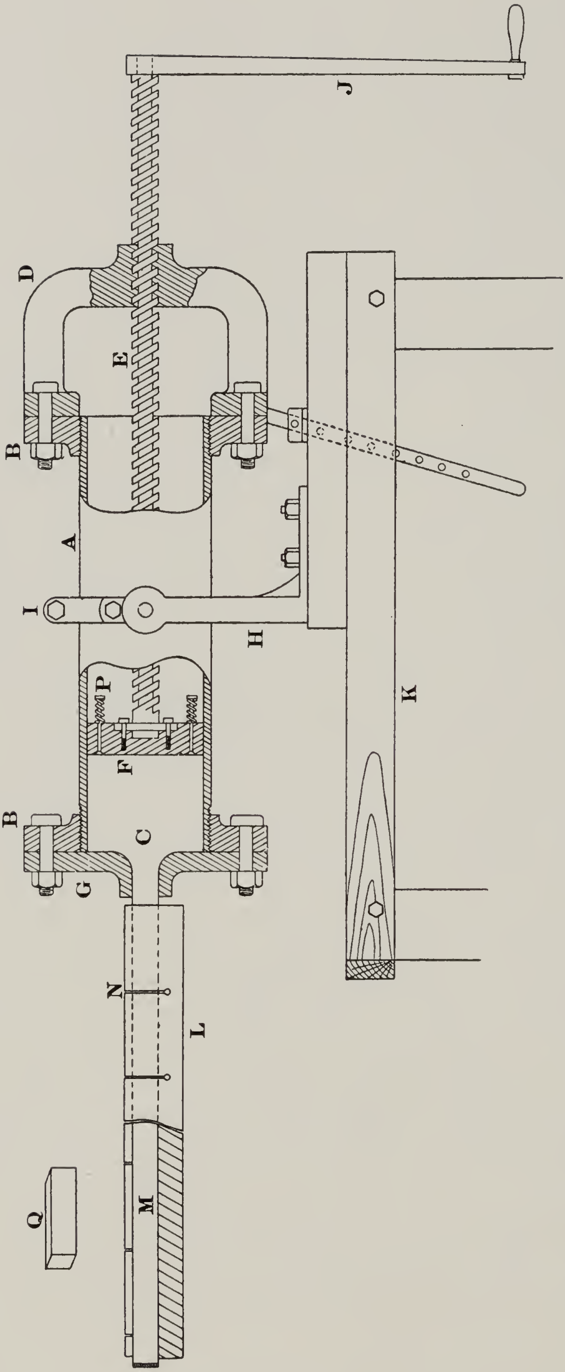
We have been accustomed to regard the supply of our better grades of clays as practically inexhaustible. Considering the great area of the whole country and the large portion still unexplored economically, this may be accepted as true. However, in those states which are most largely given over to industrial pursuits, it is scarcely wise to make this assumption. While it is true that we have large areas with great tonnages in the process of utilization and other areas known and unknown yet to be exploited, still we should not evade the fact that in some important districts the end is in sight. It is wise, therefore, to have in mind the importance of conserving the supply of the better grades of clays. This may be done by obtaining a complete knowledge of the extent and character of our clay resources; by a more precise knowledge of the requirements of the raw materials for the manufacture of the various wares; by less wasteful methods of mining; by the use of methods of purification to render clays serviceable which would otherwise be unavailable for use; by the adoption of the practice of blending clays from certain areas or districts so that there would be a more complete utilization of the output from small mines of the region or of certain strata of clays; by the avoidance of the practice of using superior material, either the raw material or the finished product, where an inferior grade would suffice.

As an instance of the importance of a more adequate knowledge of our clay resources, we may cite the diaspore deposits of Missouri. For many years flint clay deposits in certain counties of that state have been operated. A peculiar rough type of clay found in those pits was regarded as detrimental or worthless, and abandoned pits may be found today where large bodies of it were left. Within the past three years, this material has been found to be of exceptional interest and value because of the extraordinarily high content of alumina.[1]

The Physical Properties and the Methods of Testing the Clays

The methods of testing employed were, with few exceptions, those recommended tentatively by the American Ceramic Society's Committee on Standards in its report of 1918.

[1]Buehler, H. A., Biennial Report of the State Geologist of Missouri, p. 18, 1919.



A 5-inch standard pipe, machined	E Square tread screw	I Strap
B Pipe flanges	F Piston plate	J Crank
C Clay	G Die	K Table
D Yoke	H Stand	L Cutting box

M	Clay Column
N	Cutting slots
P	Pin and spring
Q	Briquet as cut, 1"x1"x3½"

Fig. 44. Hand plunger machine for molding briquets.

PRELIMINARY PREPARATION

The quantity of each sample collected by the field geologist and sent to the laboratory approximated fifty pounds weight, but was less when special circumstances made a smaller amount necessary, as in the case of samples gathered by boring with an auger.

After a careful inspection of the dried material, in which observations were made as to its general character, its degree of homogeneity, and the presence of easily distinguishable minerals, organic matter, and other impurities, the sample was crushed by passing through a set of rolls excluding, of course, any pebbles or lumps of an obviously foreign nature. The occurrence of pebbles or foreign material was quite unusual. This crushing operation was limited strictly to the breaking down of the larger lumps of clay and no grinding was done.

The powdered clay was passed through a twenty-mesh sieve, and the fines were moistened with a sufficient quantity of water to permit the working of the mass into a plastic condition of the right consistency to be molded into the test pieces. The determination of the correct consistency was dependent upon the judgment of the operator. Sometimes a few trials were necessary in order to arrive at the proper condition. Since plastic clays are workable with a fairly wide range of water content, it will be noted in the reports upon the tests of clays that in some instances a certain amount of variation occurs with the same clay. Thorough kneading or wedging, as it is called, was employed in order to insure a uniformity in the mass.

THE TEST PIECES

FORMATION

The pieces required for the testing were formed by one or the other of two methods. The method ordinarily used was to place the plastic mass in the barrel of a piston press and to force the clay to flow out through a die having an opening one inch square. The bar of clay thus formed was cut into pieces about four inches long.

This apparatus (see Fig. 44) is the same one as described and used in the "Tests on Clay Materials Available in Illinois Coal Mines," published by the Illinois State Geological Survey as Bulletin 18 of the Coöperative Mining Investigations series.

This method furnished also a means for estimating the relative ease or difficulty with which a clay would flow through a die, a factor which is of importance in some lines of manufacture.

The alternative method was to form a roll of clay of the approximate dimensions of a small brass mold and to tamp the roll into the mold, taking care to have it filled completely. The piece thus formed was of the same size as that formed by squeezing through the die.

DRYING

The test pieces were dried carefully by keeping them for a period of several hours at the room temperature, then in a drier at a temperature of 100° F., and finally at a temperature of 212° F.

RAW CLAYS: THEIR PROPERTIES AND METHODS OF TESTING

SHRINKAGE

Shrinkage is the contraction which takes place in a clay during the drying or the burning of the same. In the former case, it is due to the loss of the water which has been introduced to render it plastic and which surrounds and separates the particles. The amount of the shrinkage varies widely and may be classified[1] as follows:

	Per cent
Low	0 —3
Medium Low	3.1—6
Medium	6.1—9
Medium High	9.1—12
High	12.1 and upwards

Excessive shrinkage will render a clay unfit for use for many purposes and often causes warping or cracking.

Linear.—Immediately after forming each piece, it was marked for identification and shrinkage marks were made upon one face spaced 3⅛ inches apart. After the completion of the drying, the pieces were again measured in order to determine the amount of linear shrinkage, which was calculated as follows:

$$\text{Percentage of Linear Shrinkage} = \frac{\text{Length of plastic piece} - \text{Length of dry piece}}{\text{Length of dry piece}} \times 100$$

In many cases the linear shrinkage is also expressed in terms of the plastic length, as for example:

$$\text{Percentage of Linear Shrinkage} = \frac{\text{Length of plastic piece} - \text{Length of dry piece}}{\text{Length of plastic piece}} \times 100$$

Volume.—The determination of the volume shrinkage was made in many cases. It was done by means of a volumeter which is described later (see page 29). The results were calculated as follows:

$$\text{Percentage of Volume Shrinkage} = \frac{\text{Volume of plastic piece} - \text{Volume of dry piece}}{\text{Volume of dry piece}} \times 100$$

The method used is more refined than that employed for linear shrinkage and consequently the results are more accurate.

---

[1]A slightly modified form of the classification given by: Watts, A. S., Classification of clays on a ceramic basis: Jour. Am. Cer. Soc., Vol. 3, p. 247, 1920.

WATER OF PLASTICITY

The amount of water required for addition to a clay to render it readily workable is known as the "Water of Plasticity." It varies widely in different clays, depending upon the fineness of grain and relative amount and character of the colloidal content. It varies also with the same clay. In general, the more plastic clays have the larger content of water of plasticity and exhibit the widest variations in amounts for the individual clays. They also show the greatest strength in the dried state. The following table[1] shows the water of plasticity content of some typical clays and shales:

	Per cent	
Galesburg Shale	26.7	Good working properties
English Ball Clay M. and M. No. 1	49.3	Very plastic, rather sticky
Tennessee Ball Clay No. 3	52.5	Very plastic, rather sticky
English China Clay	44.1	Fairly plastic
Georgia Kaolin	26.2	Very plastic, rather sticky
Florida Kaolin	45.2	Good plasticity, rather sticky
North Carolina Kaolin	34.2	Slightly plastic, sticky

The calculation of the water of plasticity was made as follows:

$$\text{Percentage of Water of Plasticity} = 100 \times \frac{\text{Weight of plastic clay} - \text{Weight of clay dried at } 212^\circ \text{ F.}}{\text{Weight of clay dried at } 212^\circ \text{ F.}}$$

The water of plasticity consists[2] of the "Shrinkage Water" which is that part which is driven off during the drying period up to the time when shrinkage ceases; and the "Pore Water" or that portion which still remains when shrinkage ceases, retained in the pores of the piece until the completion of the drying has driven it all out.

Shrinkage water.—The shrinkage water was determined by measuring the volume of the test piece before and after shrinkage ceased and reporting the difference in terms of percentage of the dry weight; as, for example:

$$\text{Percentage of Shrinkage Water} = \frac{\text{Plastic volume} - \text{Dry volume}}{\text{Dry weight}} \times 100$$

Pore water.—Since the pore water is the portion of the water of plasticity retained in the pores after shrinkage ceases, it is therefore calculated as follows:

$$\text{Percentage of Pore Water} = \text{Percentage of Water of Plasticity} - \text{Percentage of Shrinkage Water}$$

Clays in which the ratio of shrinkage water to the pore water is high are likely to have excessive or sticky plasticity and to warp or crack in drying. This ratio undoubtedly bears an important relation to the strength of the unburned clay. These properties are dependent also upon other factors such as the shape and the relative proportion of the various sizes of non-plastics in the mass so that in our present state of knowledge a correlation cannot

[1]Kinnison, C. S. A study of the Atterberg plasticity method: U. S. Bureau of Standards Tech. Paper No. 46, pp. 11-12, 1915.
[2]No account is taken here of the hygroscopic water, imbibed or absorbed water.

be made. However, according to certain investigations by A. V. Bleininger[1] the best clays for glass pots and crucibles have a pore water-shrinkage ratio of 1:1.

FINENESS

The relative proportions of the non-plastic material of various sizes present in clays varies within wide limits and the choice of a clay for special purposes sometimes depends upon a particular amount or size. For example, the use of siliceous clays in the mixture for glass pots has been found of distinct advantage.

It is desirable, therefore, to have such information available and it would be of advantage to have more information about the mineral character and the physical form of the non-plastic particles.

Plasticity, drying conduct, drying shrinkage, strength and burning properties are all largely influenced by the non-plastics. In some cases the removal of non-plastics above a certain size is necessary as in the case of the manufacture of stoneware.

One hundred grams of the dried sample were shaken with 800 cc. of water in a mechanical shaker until the mass was thoroughly disintegrated. The mixture was then poured on to a set of sieves of the meshes recorded in the tests. The soft lumps of the residues were crushed by rubbing with the fingers and washed thoroughly, dried and weighed. The results are reported in the terms of the total weight of the dry clay used.

In the reports on the results of tests which follow, the classification given herewith is used:

Amount of residue *Per cent*	
0—3.5	Slight
3.6—5.5	Low
5.6—10.5	Moderate
10.6—25.5	Considerable
More than 25.5	High

SLAKING

The slaking test has been recommended as preliminary test of especial service in distinguishing between clays of high and low strength. Many clays which require thirty minutes or more to slake have high tensile and transverse breaking strength in the unburned condition. Clays which slake quickly have low or medium strength. This test is useful for a rough approximation only which should be confirmed by the usual strength tests.

An intimate mixture of equal parts of dry clay and potter's flint was moistened with water and after working to a plastic condition was shaped as a bar measuring 4 in. by 1 in. by 1 in. This bar was cut into cubes

[1]Bleininger, A. V., Properties of American bond clays, etc.: U. S. Bureau of Standards Tech. Paper No. 144, p. 51, 1920.

approximately one inch on each side. After carefully drying these, first at room temperature, then at 160°-170° F., and finally at 212° F., they were cooled, placed on wire mesh trays (four meshes to the inch), and then submerged in water at room temperature. The cubes slaked more or less slowly and the time required for this to be completed was noted. Care was taken to avoid agitation of the water during the slaking process.

TRANSVERSE STRENGTH

The strength of dried unburned clay is determined either in terms of tensile strength or the cross-breaking strength. The latter is more commonly used by American ceramists at present because of the simplicity of the apparatus and the greater uniformity of results obtained. A modulus of rupture of less than 200 pounds per square inch may be regarded as low; between 200 and 400 pounds per square inch as good; and above 400 pounds as high. This test is of use in the valuation of all clays but especially those which are be used alone or with other clays, and without the addition of non-plastics as such. The washing of the clay may or may not impair its strength.

Test bars 6 in. by 1 in. by 1 in. were formed according to the methods previously described, dried first at room temperature, then at 140° to 150° F. for 24 hours, and finally at 212° to 220° F. for 24 hours. After removal from the oven, and cooling to room temperature, the pieces were then supported upon knife edges placed five inches apart. At a point midway between the supports rested the knife edge of a yoke from which hung a pail. A stream of sand was fed into this pail until the weight was sufficient to break the bar.

The result of the test was recorded as the modulus of rupture which was calculated as follows:

$$\text{Modulus of Rupture} = \frac{3 \times \text{Weight in pounds} \times \text{Distance between supports}}{2 \times \text{Breadth} \times \text{Depth}^2}$$

Twenty pieces were tested in all cases where sufficient material was at hand. The final result reported was the average of all the values which did not vary more than 25 per cent of the maximum.

The "modulus of rupture" classification used in describing the results of tests of transverse strength is the same as that given below for bonding strength.

BONDING STRENGTH

It is the practice in the manufacture of many kinds of wares to use more or less non-plastic material containing particles of varying size and shape, as, for example, in furnace blocks, fire brick, crucibles, glass pots, abrasive wheels, architectural terra cotta, and zinc retorts. For such uses, it is highly important that the clays used should permit such admixtures

with a retention of maximum strength. Ordinarily the addition of considerable amounts of non-plastics results in a decrease in the cross-breaking strength as compared with that of the pure clay. In some instances there is little change and sometimes an increase. The following classification proposed by Professor A. S. Watts,[1] slightly modified, has been employed:

Modulus of Rupture

	Lbs. per sq. in.
Low	0—100
Medium Low	101—200
Medium	201—400
Medium High	401—800
High	801 and above

Equal parts of clay and standard sand[2] were brought to a plastic condition by the addition of water and thorough wedging. Test pieces were formed from this mixture. The method of preparation, the size, the conditions of drying and mode of breaking were similar to those described under "Transverse Strength."

The results are reported in terms of the modulus of rupture, which is calculated in the manner already described.

BURNED CLAYS: THEIR PROPERTIES AND METHODS OF TESTING

PYROMETRIC METHODS USED

The test pieces prepared for the determination of the drying shrinkage were burned in a coal-fired laboratory test kiln of the down draft type, having a chamber capacity of approximately 27 cubic feet. The normal rate of firing was:

From room temperature to 572° F.	9 hours
From 572° F. to 1112° F.	6 hours
From 1112° F. to 1382° F.	12 hours
From 1382° F. to 1850° F.	7 hours
From 1850° F. to finish	45°—54° F. per hour

Ordinarily, the trial pieces were placed in closed saggars to protect them from the flames and dust carried by the draught through the kiln.

A separate burn was made for each of the several pyrometric cones indicated in the reports on the tests, excepting as it became desirable in some cases to set the kiln so that test pieces could be drawn from time to time as the desired cone-temperature was reached.

[1]Watts, A. S., Classification of clays on a ceramic basis: Jour. Am. Cer. Soc. Vol. 3, p. 247, 1920.

[2]Standard sand is prepared especially for use in the testing of cement. It is sized to pass a twenty-mesh sieve (0.0328-inch hole, 0.0172-inch wire) and is retained on a twenty-eight mesh (0.0232-inch hole, 0.0125-inch wire).

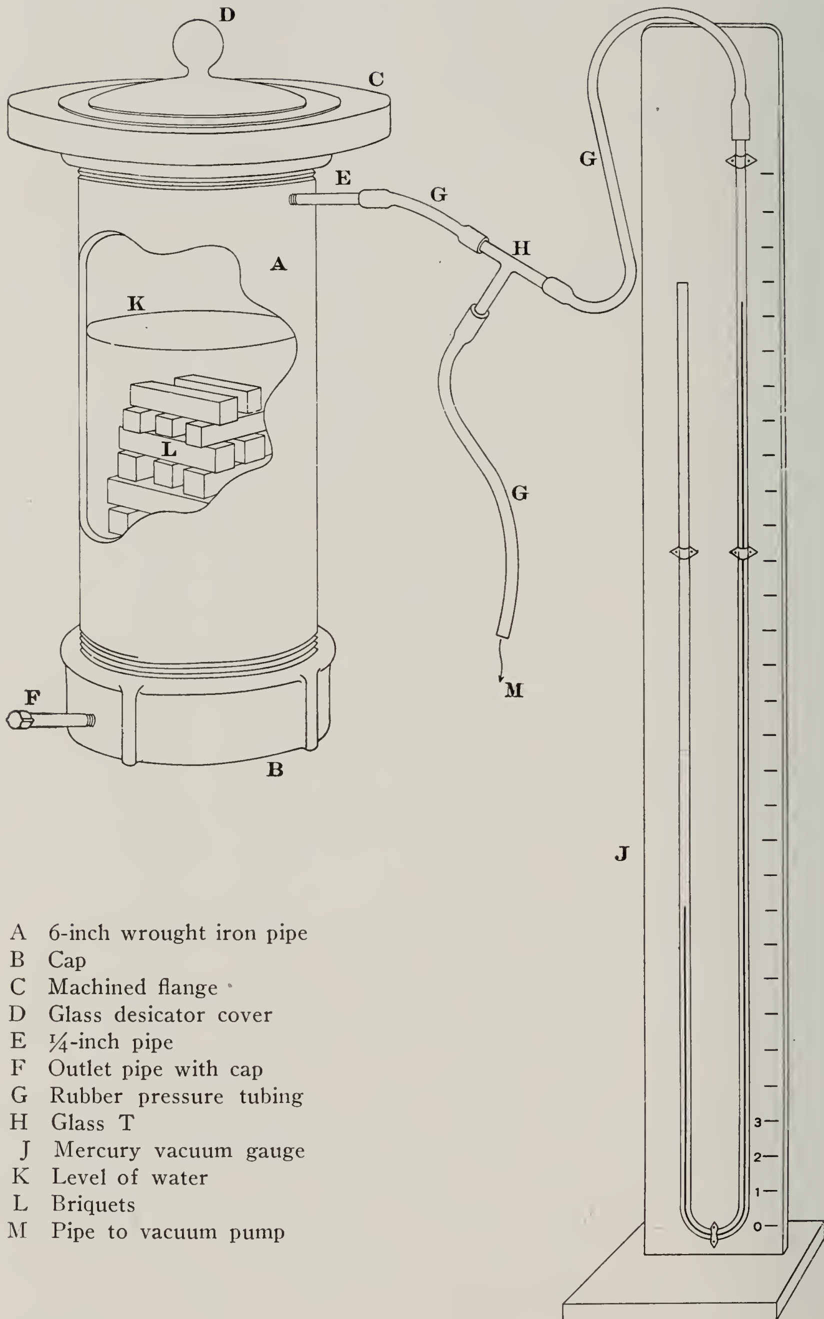
The pyrometric cones used were those made by Professor Edward Orton, Jr., of Columbus, Ohio. With respect to the temperature equivalents of these cones, it should be borne in mind that the pyrometric cone is a measure of the effect of the time-temperature relation as has been repeatedly pointed out but often disregarded. Therefore, the temperature at which a cone "goes down" is dependent upon the rate of firing. This has been carefully investigated by the Bureau of Standards and is discussed in a paper on "The Function of Time in the Vitrification of Clays," published as Technologic Paper No. 17. In the following table, a comparison is made of the cone-temperature scale: Scale (a) is as usually given, and scale (b) is as reported in the paper referred to when the rate of heating was at 49.5° F. per hour, which is nearly that used in these burns.

COMPARISON OF TWO CONE-TEMPERATURE SCALES

Cone	(a) Usual Scale	(b) Rate = 27½° C. per hour	
	Deg. F.	*Deg. C.*	*Deg. F.*
010	1742	885	1625
09	1778	930	1706
08	1814	970	1778
07	1850	975	1787
06	1886	1000	1832
05	1922	1035	1895
04	1958	1055	1931
03	1994	1065	1949
02	2030	1070	1958
01	2066	1080	1976
1	2102	1085	1985
2	2138	1090	1994
3	2174	1110	2030
4	2210	1125	2057
5	2246	1135	2075
6	2282	1140	2084
7	2318	1155	2111
8	2354	1170	2138
9	2359	1190	2174

A thermo-electric pyrometer was used in each burn in order to determine the rate of increase of temperature. It was thought impracticable to rely solely upon the pyrometer in finishing the burns because of the impossibility of grouping the test pieces within or without the saggars close enough to the thermocouple to insure certainty regarding the uniformity of the temperature distribution, whereas the cones could be scattered throughout the kiln where needed.

Two pieces were burned at each temperature indicated in practically every case, and an average taken of the results obtained.



A 6-inch wrought iron pipe
B Cap
C Machined flange
D Glass desicator cover
E ¼-inch pipe
F Outlet pipe with cap
G Rubber pressure tubing
H Glass T
J Mercury vacuum gauge
K Level of water
L Briquets
M Pipe to vacuum pump

FIG. 45. Apparatus for saturating briquets in vacuo.

BURNING SHRINKAGE

The shrinkage resulting from burning is the contraction due to the loss of water and other volatile matter, a certain amount of condensation of the components, and the softening of the mass with the consequent closing up of the voids by the more fluid portions. A high shrinkage may lead to cracking or warping of the piece and is avoided therefore in the manufacture of all ware of complicated form or large size. The following classification proposed by Professor A. S. Watts, slightly modified, is presented for comparison:

Total Shrinkage at Cone 10

	Per cent
Low	0 — 4
Medium Low	4.1— 8
Medium	8.1—12
Medium High	12.1—16
High	16 and above

In the "Results of tests" included in this report, the term "Burning shrinkage" means linear burning shrinkage in every case.

POROSITY

Porosity is the ratio between the volume of the pores and the volume of the whole piece. The volume of the pores was determined by saturating the piece with water in vacuo (see Fig. 45) and noting the weight of the water absorbed. The volume of the piece thus saturated was obtained by measuring the amount of displacement caused by its introduction into a modified form of the Seger volumeter. This apparatus consists of a large-size glass bottle with a wide neck covered by a glass cap ground to fit snugly. To the side of this bottle is connected a burrette or graduated glass tube, which permits a reading of any change of volume of the contents of the large bottle. The per cent porosity is calculated as follows:

Saturated weight — dry weight = weight of water absorbed
Weight of water absorbed gives volume of water absorbed
Volume of water absorbed = volume of pores

$$\frac{\text{Volume of pores}}{\text{Volume of test piece (including pores)}} \times 100 = \text{Percentage of Porosity}$$

COLOR

The color changes at the various cones were noted.

FUSION, OR DEFORMATION TESTS

The fusion or deformation tests were made in a Fletcher furnace for the lower temperatures and in a Deville furnace for the more refractory materials. The latter is operated by placing the test pieces in a crucible, surrounding them with coke, and forcing the combustion with a low pres-

sure air blast. The test pieces were molded into the form of four-sided pyramids measuring 0.23 inches along each edge of the base and 1.2 inches high. Standard pyrometric cones made by Professor Edward Orton, Jr., were placed in the furnace with the test pieces to serve as indicators of the cone temperatures reached.

In the reports of the results of tests, clays which deform below cone 27 are termed *non-refractory,* those which deform between cones 27 and 31 inclusive, *refractory,* and those which deform at cone 33 and above, *highly refractory.*

DISTRIBUTION OF ILLINOIS CLAYS

By C. R. Schroyer

Refractory clay is restricted in Illinois to the basal part of the Pennsylvanian ("Upper Coal Measures") and to the younger embayment deposits of Cretaceous-Tertiary age. A few local developments are associated with other horizons, usually as residuals above limestones, but such occurrences are rare and not of great importance. The clays will be discussed in order, as: (1) Clays of the embayment area, (2) Clays of Pennsylvanian age.

Geographically the refractory clays of Illinois are to be found (1) in the extreme southern counties; (2) in a narrow zone extending from East St. Louis to Rock Island; and (3) locally along Illinois River in LaSalle and Grundy counties. Fig. 43 indicates the general distribution of refractory clays.

The southern clays are part of the younger embayment deposits and are found in Pope, Massac, Pulaski, Alexander, Union, and Johnson counties. The "pocket" deposits near Mountain Glen, Union County, are the most important and have furnished the highest grade clay. Others of a similar nature are found near Grand Chain, Pulaski County. In the counties adjoining Ohio River, bedded clay is widely distributed but is not always of a quality desirable for commercial purposes. Figure 46 shows the embayment deposits.

The zone extending from East St. Louis to Rock Island (see Fig. 43) includes parts of St. Clair, Madison, Calhoun, Greene, Pike, Scott, Adams, Brown, Schuyler, McDonough, Fulton, Warren, Mercer, Rock Island, and Henry counties. While clay is quite generally present at the Cheltenham horizon throughout this entire belt, it is only locally of commercial value, as at Alton, Madison County, Alsey, Scott County, Colchester and Macomb, McDonough County, and Rock Island, Rock Island County.

In La Salle and Grundy counties at the base of the Pennsylvanian there is also a clay of refractory value. Pits are worked near Utica and Ottawa, and mines near Oglesby and Marseilles. In the vicinity of Goose Lake, Grundy County, there is a partially developed deposit which contains lenses of a semi-flint type of clay.

A report by Stuart St. Clair gives in some detail a discussion of the Union County clays.[1] E. F. Lines has studied the stratigraphy of the Cheltenham clay of Illinois.[2] As those publications are still available, only such of the matter of those reports will be repeated as is necessary for clearness.

In the introduction a general discussion has been made of the classification of clays, their properties and uses, and methods of testing. For a discussion of the character and origin of clays, the reader is referred to Bulletin 9[3] of the Survey.

CLAYS OF THE EMBAYMENT AREA

Long after the Pennsylvanian ("Coal Measures") shales, limestones, sandstones, and coals had been deposited, and after the surface of these formations had been weathered and eroded, the level of the sea relative to the land changed so that a wide open bay extended from the Gulf of Mexico northward into southern Illinois. Debris carried into this basin from the bordering land formed interstratified beds of sand, silt and clay, which make up the embayment deposits (see fig. 46) and include the refractory clays of southern Illinois.

Paleozoic Floor and Border

Beds of Paleozoic age border the embayment deposits on the outer rim and presumably form the floor of the entire basin. Their decayed products have been the source of the younger sediments. In Illinois these Paleozoic rocks are of Mississippian and Devonian age. The Mississippian beds forming most of the eastern and northern border are cherty limestone and shale with minor horizons of sandstone. The high bluff of a former channel of Ohio River roughly parallels embayment deposits on the north and rises at New Columbia to a height of 150 feet above them. Erosion has exposed Mississippian beds in southwestern Pope, central Massac, and Pulaski counties south of this channel, either as highland inliers or as bordering fringes at the north of the embayment deposits.

In Alexander and Union counties older beds of Devonian age border the embayment area and form the highlands of southwestern Illinois. These cherts and decayed siliceous rocks overlie Alexandrian and Ordovician limestones which outcrop in the bluffs of the Mississippi River flood-plain.

Correlation and Division of the Embayment Deposits

From certain features common to the embayment deposits and other beds elsewhere, and from the continuity of connection at the south as well as from an occasional fossil, these beds are known to be of Cretaceous and

[1]St. Clair, Stuart, Clay deposits near Mountain Glen, Union County, Illinois: Ill. State Geol. Survey Bull. 36, pp. 71-83, 1920.

[2]Lines, Edwin F., Pennsylvanian fireclays of Illinois: Ill. State Geol. Survey Bull. 30, pp. 61-73, 1917.

[3]Rolfe, C. W., Geology of clays (part of paving brick and paving brick clays of Illinois): Ill. State Geol. Survey Bull. 9, pp. 1-46, 1908.

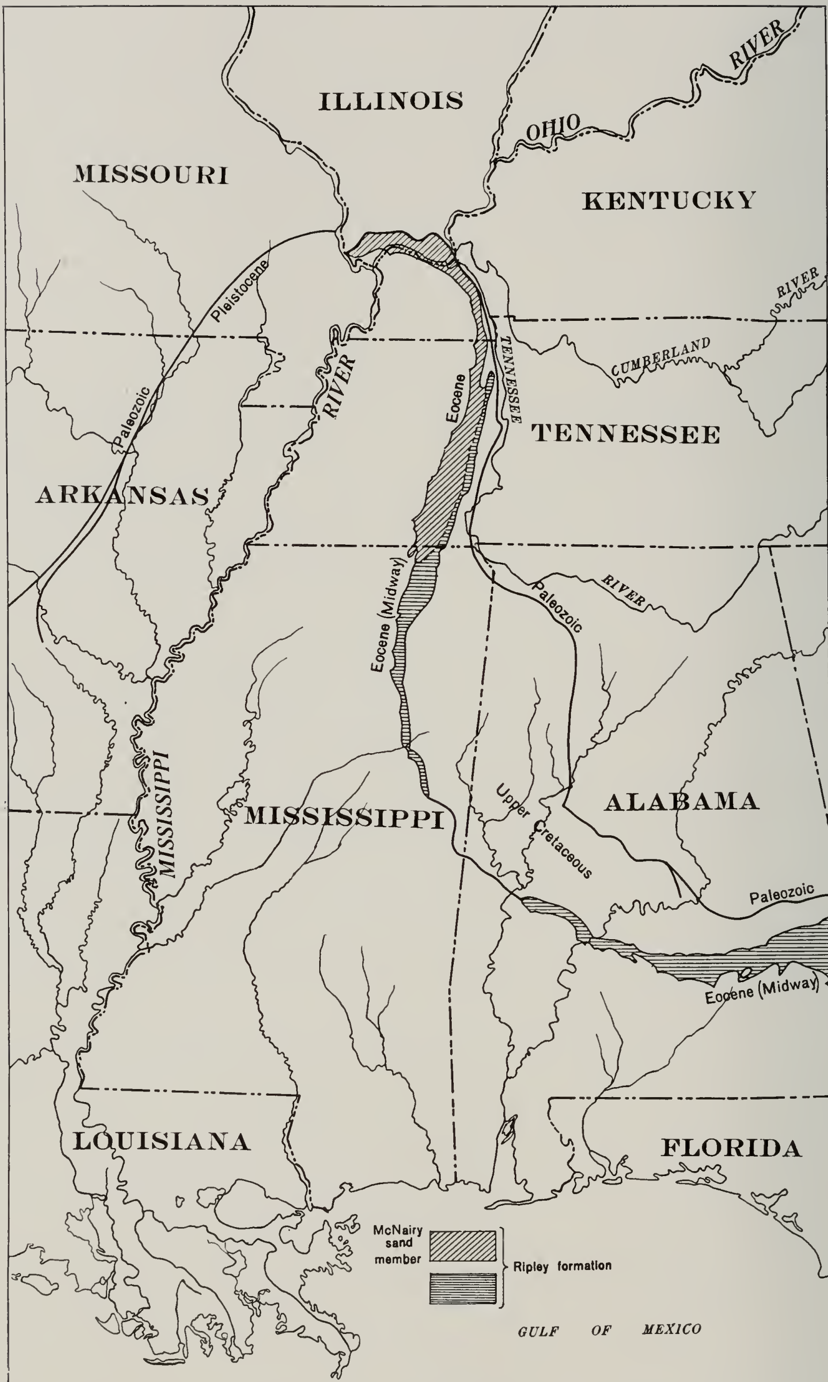


FIG. 46. Map showing the outcrop of the embayment deposits in Illinois with their relationships to similar deposits farther south. The heavy line labelled "Paleozoic" which swings north from Arkansas into Illinois and thence south into Alabama, is the boundary of the deposits laid down in the embayment which extended northward from the Gulf in Cretaceous and Tertiary times. Only the outcrop of the Ripley formation is shown. South of the Ripley in Illinois Eocene and younger formations are uppermost, and remnants of these younger formations are found even in and perhaps beyond the area mapped as Ripley. (After Stephenson.)

Tertiary age. In the states farther south, where there are definite breaks between formations, it has been possible to draw lines that definitly subdivide these deposits, as indicated in the accompanying table. In Illinois, however, with only the outer margins present it is difficult and in some cases probably impossible to separate them into distinct horizons.

Each formation listed in Table 44 represents a transgression of the sea and each break represents a period of erosion. How far north these beds extended or how thick they were originally can not be determined from their present distribution. Small outliers are found far beyond the areas of connected strata. For example, at New Columbia, Massac County, and south along the bluff such remnants are found both as terraces and as thin beds over the Paleozoic uplands, 150 feet or more above the present valley level, as indicated by the fact that a well on the bluff southeast of New Columbia 18 feet deep ended in red sand by a section of the road from the levee to the top of the bluff at this place:

Section of bluff at New Columbia

	Thickness *Ft.*	*In.*
9. Loess	10	..
8. Gravel	..	6
7. Sandstone, platy, red and gray	6	6
6. Sandy beds, light in color	10	8
5. Sandstone, shaly; weathers to 3-inch beds	6	..
4. Clay shales, sandy, white and buff interbedded	7	6
3. Clay, sandy, white with iron-colored streaks	3	..
2. Partly covered	5	..
1. Sandstone (Mississippian)	100	(Bar.)

A section measured near Rosebud gives similar indications:

Section 2 miles south of Rosebud, Pope County, in the SE. ¼ sec. *33, T. 14 S., R. 6 E.*

	Thickness *Feet*
6. Gravel	2±
5. Clay, light colored, sandy, and thin beds cemented by iron	16
4. Shales, buff and gray, sandy; thin compact irony beds near the top.	6½
3. Sandy beds, partly covered, variegated, micaceous	22
2. Covered	40 (Bar.)
1. Limestone (Mississippian)	25

This bluff rises 150 feet above the level of the present alluvial deposits and the capping suggests that it has been completely buried by a filling of sand and clay.

Near Vienna, Johnson County, small terrace remnants of bluish white stratified clay shale interbedded with hard red, sandy beds also suggests the former presence of more extensive deposits. Such small remnants are

TABLE 44 *Subdivisions of the embayment deposits, recognized by various authors*

Description of Horizon	Approximate Thickness	From Professional Papers [a] 81, 90J, 95F, 120C, and 120H		From Water-Supply Paper 164[b]	System	Relations In Illinois
	Feet	*Formations*		*Formations*		
Sands with clay lenses and greensand. Characteristic life remains	200±	Jackson			Tertiary (Eocene)	Not represented in Illinois
		(Erosion interval)		?		
Highly fossiliferous greensands not recognized outside of the Alabama area	30 to 40	Gosport	Claiborne 450±	Lagrange		
Calcareous, argillaceous, and glauconitic fossiliferous sands	100 to 150	Lisbon				
Siliceous claystone, calcareous and fossiliferous toward the east	200±	Tallahatta				
		(Erosion interval)				
Laminated, sandy clays and cross-bedded, calcareous sands carrying fossils and some greensand	175	Hatchetigbee	Wilcox 850±			Represented in Illinois. The high grade clays of Mountain Glen, Grand Chain and possibly Raum, questionably referred to this horizon. Continuous deposits cover a triangular area in the extreme southern part of State
Sandy clays and thick lenses of calcareous glauconitic sands. A bed of lignite at the base	?	Bashi				
Gray and yellowish cross-bedded sands and sandy clays, massive below and laminated above	140	Tuscahoma				
Sandy glauconitic beds alternating with grayish, calcareous clays. Lignite bed at base	200	Nanafalia				
		(Erosion interval)				
Lignitic ferruginous sandy clays and beds of lignite or coarse, micaceous highly colored sands with micaceous clays. Greensand	?	Naheola Sucarnochee Clayton	Midway	Porters Creek		Probably pressent, but no distinctive marks of identification
		(Distinct erosion interval and faunal change)				
Sands usually light in color, but with considerable variation; pink, light yellowish, brown, and locally also leaden or slate colored clay, 10 to 20 or more feet thick. Iron concretions characteristic. Calcareous and glauconitic beds	250 to 300	(Thought to be of the same age as the Selma farther south)		Ripley (McNairy sand member at the north)	Cretaceous	Extends as a curved belt 5 to 15 miles wide about the outer margin of the embayment deposits. Known from deep excavation at Cairo
Clay of a light leaden gray or greenish color when dry; somewhat darker when wet. Greensand present in some layers. Calcareous shells at the south	950			Selma		Absent
Sands which locally contain calcium carbonate and greensand	450			Eutaw		
Sands and clays of shallow water origin	1000±			Tuscaloosa		
		(Distinct break)				
		Paleozoic formations				

[a]–Stephenson, L. W., Cretaceous deposits of the eastern Gulf region: U. S. Geol. Survey Prof. Pape 81, 1914.
Stephenson, L. W., The Cretaceous-Eocene contact in the Atlantic and Gulf coastal plain: U. S. Geol. Survey Prof. Paper 90J, 1915.
Berry, E. W., Erosion intervals in the Eocene of the Mississippi embayment: U. S. Geol. Survey Prof. Paper 95F, 1915.
Cooke, C. W., and Shearer, H. K., Deposits of Claiborne and Jackson age in Georgia: U. S. Geol. Survey Prof. Paper 120C, 1918.
Stephenson, L. W., A contribution to the geology of northeastern Texas and southern Oklahoma: U. S. Geol. Survey Prof. Paper 120H, 1918.
[b]–Glenn, L. C., Underground waters of Tennessee and Kentucky west of Tennessee River and of an adjacent area in Illinois: U. S. Geol. Survey Water-Supply and Irrigation Paper No. 164, 1906.

known in the Devonian area of Alexander and Union counties as far north as Mountain Glen, and the deposits of refractory clay at that place are probably outliers. Still farther north clay has been dug at an elevation of about 625 feet above sea level, northwest of Alto Pass near the north line of Union County. Outliers of sand and thin-bedded clays are found west of Pomona in Jackson County at an elevation of about 650 feet above sea level. This clay is so white that it has been used by the farmers for white wash and paint.

CRETACEOUS SYSTEM

UPPER CRETACEOUS SERIES

RIPLEY FORMATION

The four lower embayment formations listed in the table are of Cretaceous age but only the highest of these, the Ripley formation, extends into Illinois. The northern extension of this formation is composed largely of loose sands and sandstone, and is known as the McNairy sand member. The McNairy extends in a curved belt across southwestern Pope, southern Massac, and central Pulaski counties, and in a constricted narrow belt across Alexander County, terminating not far from Fayville at Mississippi River. The width of this belt varies from 10 miles north of Metropolis to less than half that width in central Alexander County. Younger beds of Tertiary and Quaternary age overlie most of this area.

Lithologic Character.—In Tennessee the Ripley formation is composed mostly of stratified, variegated sands, that are commonly rich in iron and contain "pipes" and irony masses. "The sands are usually fine gravel and between them are found beds of gray lignite or yellow sandy micaceous clay."[1] Drying cracks now filled with limonite indicate periods of exposure early in the history of the deposit.

In Kentucky the Ripley is a "black clay in very thin laminae, separated by fine white and highly micaceous sand; beds of sharp angular white and yellow micaceous sand 100 feet thick."[2]

In Illinois the fewness of Ripley exposures makes study of this horizon difficult. In general, however, the formation is made up of variegated sands interstratified with beds of gray, leaden, or slate-colored clay, 10 to 20 feet or more thick. The sands are commonly rich in iron, and ironstone layers and concretionary masses are abundant. The clays of Massac County are of this age.

Sections of the McNairy sands of the Ripley formation in Illinois follow:

---

[1]Nelson, W. A., Clay deposits of West Tennessee: Geol. Survey of Tennessee Bull. 5, p. 11, 1911.
[2]Gardner, James H., Kentucky Geol. Survey Bull. 6, p. 83, 1905.

Log of the Eichenseer well, one mile below Yates Landing in the SW. ¼ sec. 2, T. 15 S., R. 2 E.

Description of strata	Thickness *Feet*	Depth *Feet*
Loam and loess	18	18
Gravel, coarse	3	21
Sand, white	30	51
"Potters clay," white	6±	57
Sand, white, with small lumps of clay	70	127

Section of east bank of drainage ditch 300 yards north of Ohio River

	Thickness *Ft.*	*In.*
5. Soil	1	3
4. Loess	5 to 15	..
3. Gravel and sand, stained brown or red by iron; compact at base	1	3
2. Clay, bluish, micaceous, sandy, with thin lenses of sand	2	6
1. Sand and clay interbedded and slumped together	8	10

Log of the Stoner well in sec. 28, T. 15 S., R. 6 E.

Description of strata	Thickness *Feet*	Depth *Feet*
Clay and "loam," yellow	10	10
Sand, fine	2½	12½
"Soapstone," dark compact clay, with lignite	9	21½
Sand and clay, red in color; some harder irony layers, others white and buff	28	49½
Rock, hard; bottom of well	..	..

Section half a mile west of Round Knob

	Thickness *Ft.*	*In.*
4. Gravel; unmeasured	..	..
3. Clay, red	4	..
2. Clay, white and pink	6	6
1. Sand, red and white, case hardened ferruginous layers	18	..

TERTIARY SYSTEM

EOCENE SERIES

MIDWAY FORMATION

The Midway formation includes the oldest beds of Tertiary age, and south of Illinois it rests with marked unconformity on the underlying Cretaceous.

Only in the vicinity of Caledonia Landing east of Olmsted have exposed deposits in Illinois been correlated with the Midway, although in wells at

Cairo and Mound City, beds 100 feet thick have been classified as Porters Creek [Midway].[1]

This phase of the Midway extends westward from Caledonia as a belt a few miles wide.

Lithologic Character.—Sections indicating the character of the Midway, especially its variability, follow:

Section of the Midway formation at Caledonia Landing[2]

		Thickness *Feet*
8.	Gravel, sand, and shale fragments	5
7.	Shale fragments, light gray; probably "in place"	25
6.	Shale, light gray, lumpy	11
5.	Clay, sandy, greenish gray and seamed by ferruginous clay "dike"	1
4.	Clay shale, dark gray or drab, seamed by ferruginous clay "dike"	6
3.	Shale fragments, light gray	3
2.	Clay shale, brown to black, "fat," lumpy	3
1.	Shale, debris, dark and light gray	2
	Water level	

The section varies from place to place as is evident from the following:

Section of Midway formation a quarter mile upstream from Caledonia Landing

		Thickness *Ft.*	*In.*
12.	Gravel, chert pebbles	1±	..
11.	Shale, gray, sandy, small stains of lignite	8	..
10.	Sand, small hollow iron concretions	3	6
9.	Sands and clay, buff and gray, partly covered	5	6
8.	Hematite layer	..	2
7.	Sand	..	6
6.	Iron oxide bed, concretionary, platy	..	4
5.	Sand, gray, micaceous	2	..
4.	Ferruginous bed	..	10
3.	Sand, buff, and iron concretions	1	6
2.	Concretionary ferruginous bed, indistinct fossil casts (?)	..	8
1.	Covered	10 (Bar.)	
	Water level		

The nature of the Midway beds at this place strongly suggests beds of Ripley age.

Less than a quarter mile below Caledonia Landing, a solid bank of 55 feet of dark shale, almost black when wet, but light gray when dry, rises above the water level. Upon drying it cracks out in characteristically large, roughly angular blocks. This deposit is the "soapstone" of the Midway group.

---

[1]Purdy, Ross C., and DeWolf, Frank W., Ill. State Geol. Survey Bull. 4, p. 143, 1907.
[2]Ibid., p. 144.

Section of Chalk Bank 2½ miles above Caledonia

	Thickness Ft.	In.
Pleistocene and Recent deposits		
11. Soil, grading into loess at base	1	6
10. Loess	15	..
Lafayette formation		
9. Clay, sandy and bedded, below; angular chert pebbles in clay above; a re-worked base	3	..
Midway formation		
8. Sand and limonite beds; cross-bedded, clayey above, stringers of clay pebbles in base	10	..
7. Sand, very fine, ash-colored; limonite concretions, clay lenses near top; "Petrified hickory"; wash shows greensand	30	..
Sharp break		
Ripley formation		
6. Clay, chocolate, stained by plant remains	..	6
5. Sand, ash-colored and buff	8	..
4. Covered	5	6
3. Clay	3	..
2. Limonite, concretionary	1	..
1. Clay shale, micaceous, thinly bedded, numerous pyrite concretions; several seams colored dark by lignite and fragments of plants (approx.)	10	..
Water level		

This horizon is replaced but a short distance below by clay and sand in which limonite and lignite streaks are common.

Section in ravine three quarters mile northwest of Chalk Bank

	Thickness Feet
Midway formation	
5. Clay shale, dark	10
4. Sand in loose beds, containing greensand; grades into clay above	4
3. Conglomerate, rich in iron oxide; voids filled with sand	1
2. Greensand, as above, a few quartz pebbles	3½
1. Clay shale, impure	3

The greensand of the preceding section is about 30 feet higher than the base of the Chalk Bank section and is exposed in several hollows above Chalk Bank. Greensand is also reported from near low water mark at Hillerman's Landing, but was not seen in place.

Wilcox Group

The Wilcox group includes the youngest beds of Tertiary age in Illinois. They are exposed over the higher areas of southern Pulaski and Alexander counties. A section at Fayville of beds which are regarded as belonging to this horizon is as follows:

Section including the Wilcox group, at Fayville

	Thickness Ft.	In.
7. Soil	1	3
6. Loess	10	..
5. Clay and sand, ash-colored	4	..
4. Sand, buff, partially cemented	5	6
3. Conglomerate layer cemented by iron; pebbles up to 3 inches in diameter	1	6
2. Clay, lignitic	3	..
1. Clay, sandy, micaceous	4	..

On the land of the Aetna Powder Company other Wilcox deposits are found: 9 feet of light drab to gray laminated clay with partings of mica and an occasional thin seam of sand is exposed at the first separator house; and in the cut made for a railroad spur there are 20 feet of loose white sand. Pits dug for clay have penetrated similar sands in the Mountain Glen district of north central Union County, and the sand beds at Hillermans Landing and Grand Chain are also similar. These facts suggest but do not prove that the white clays above the sands at Mountain Glen and Grand Chain may be at the same horizon in the Wilcox group. The distribution and a similarity of elevation suggest that they are isolated deposits overlying an irregular erosion surface.

PLIOCENE SERIES

Certain beds formerly included in the Lafayette formation have recently been shown[1] to be parts of different deposits and to belong to several formations, most of which are as yet unnamed. "It is believed to be made up of unrelated or distinctly related materials that * * * consist in the main of more or less modified parts of the underlying formations, including some residuum and colluvium, and of terrace deposits of Pliocene and Quaternary age."[2]

The Pliocene deposits in Illinois show evidences of transportation and will probably prove to be terrace remnants. Chert pebbles, angular masses, and rounded quartz pebbles predominate. Lenses of clay or of clay and sand occur, generally below the gravel, and there is commonly sufficient fine material to fill all voids. The common color is red. The pebbles often show a polish akin to a desert polish over a maturely etched surface. Large masses display the same polish as do small rounded ones.

Huge masses of conglomerate are included within other conglomerates, perfect polished surfaces are a second time recoated with rough red iron cement, features which are to be taken as evidences of re-working, transportation, and redeposition.

[1]Shaw, E. W., The Pliocene history of northern and central Mississippi: U. S. Geol. Survey Prof. Paper 108 H, 1918.

[2]Ibid., p. 161.

These beds may once have covered the older formations and overlapped them at the north. However that may be, erosion has since removed all but small terrace shoulders on the slopes or isolated remnants over the higher areas.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

Loess Formation

Above the gravel and red clay horizon is a sheet of loess, which extends as a mantle over and beyond the embayment deposits and except where removed by erosion is everywhere present. It is composed of a porous, buff, silty clay which stands in vertical walls. In color it varies from yellowish brown to red. The thickness of this bed varies from place to place, ranging from a mere trace to as much as forty or fifty feet.

RECENT SERIES

Alluvial Deposits

The latest deposits of this region, the river flood-plains, form the principal surficial covering over the continuous elongate lowland area which extends from Ohio River above Bay City westward past Brownfield, New Columbia, Belknap, and Ullin on the south, and Temple Hill, Grinnell, and Pulaski on the north. They extend from Mound City west to near Fayville where Cache River occupies a part of this flat which was at one time the flood-plain of Ohio River. Another smaller area extends from below Hamletsburg to near Brookport.

"There are two distinct flood-plains though not always present at one locality. The upper or 'second bottoms' lies 45 feet or more above low water, and has a much greater extent than the lower plain, more recently developed at a level about 20 feet above low water. The lower flat is subject to partial or complete overflow at the present time, while the upper is for the most part, at least, above high water.

"The composition of these alluvial deposits is commonly revealed along river bluffs and in water wells. Sandy clay predominates, but this gives way, on the one hand, to fine gray or blue clay or nearly normal loess, while, on the other, to beds of gravel one foot or more thick and composed of flint and sandstone pebbles commonly as much as two inches in diameter. Vegetal remains, leaves, and wood are often interbedded with the silts while other clays are darkly colored with organic matter.

"The thickness of the alluvium can be obtained only from well borings, and as these rarely penetrate more than a few feet to water, it is not possible to learn the thickness at many places in this area. At lower places along the Mississippi it is thought to be as much as 100 and 200 feet thick."[1]

[1]Purdy, R. C., and DeWolf, F. W., Preliminary Investigations of Illinois Fire Clay: Ill. State Geol. Survey Bull. 4, pp. 145-146, 1907.

These deposits are not utilized at the present time. In the days when pottery was manufactured at Metropolis, slip clay was dug from the Ohio River silt near that place.

ELEVATION OF THE ILLINOIS EMBAYMENT CLAYS

A study of the relative elevation of the various clay deposits is of interest as bearing on the mode of origin and age of the different clays. It is necessary, however, to remember that noted changes of elevation have taken place in areas not far distant from southern Illinois in recent times, as for example in the Reelfoot Lake district of northwestern Tennessee, and that similar changes may have affected this area.

Approximate present elevations of clay beds above sea level

Clay "diggins," Raum, Pope County	420 to 440
White and lignitic clays at Grand Chain, Pulaski County	425
Mountain Glen clays, Union County	400 to 460
Clay 1½ miles west of Alto Pass, Union County	625±
Clay west of Devonian ridge at Kaolin, Union County	560±
Clay east of Devonian ridge at Kaolin, Union County	560±
Clay in southern Jackson County	600 to 650

The first three clays are similar in many ways and all are lignitic except possibly the Raum clay, in the description of which no mention was made of lignite. The last four clays are similar, in that they are sandy and generally have a greenish gray tone.

Similarity in elevation of the first three clays listed above, namely, those at Mountain Glen, Grand Chain, and Raum, suggests that they may have been of the same age, though the isolation of their positions makes accurate determination of the age impossible. Terrace clay 100 feet or more above the better clay of the Union County area points to at least one period of clay formation subsequent to that of the Mountain Glen clay.

The fact that pure, white, plastic clays of this type are present in small isolated areas would seem to indicate that much greater quantities of such fine silt were washed into the larger embayment area from the extensive Mississippian limestone outcrops and that the present deposits are mere remnants. In most cases sandy impurities become mixed with the silt in transportation and the outer deposits are more sandy in texture. Such clays are found in the Wilcox group (La Grange formation). "The clays * * * vary from pure, fine-grained, plastic material to sandy, silty clays that are often dark from organic matter or black from lignite. The clays of the lower part of the formation are characteristically fine-grained, pure, plastic, and either very light colored or white."[1]

[1]Glenn, L. C., Underground waters of Tennessee and Kentucky west of Tennessee River, and in adjacent area in Illinois: U. S. Geol. Survey Water Supply and Irrigation Paper 164, p. 34, 1906.

As mentioned, clay dug near Hickory, Kentucky, and north of Mayfield is identical in color, texture, and other physical properties with that at Mountain Glen. That clay is of Wilcox age. All these evidences point to the Wilcox age of the Illinois clays.

The higher sandy terrace clays resemble the greenish gray clays at Wyckliff, Kentucky, and a later Wilcox age is suggested by their position.

The sandy, bedded clays of Massac and Pulaski counties are in older beds referred to the Midway and McNairy members.

Field and Laboratory Notes on the Embayment Clays

Field Notes by C. R. Schroyer
Tests by C. W. Parmelee

UNION COUNTY, MOUNTAIN GLEN AREA

PITS OF THE ILLINOIS KAOLIN COMPANY

The large pit, known as the "K" pit, of the Illinois Kaolin Company is located in the SW. ¼ sec. 35, T. 11 S., R. 2 W., about a quarter mile west of Kaolin Station on the Mobile and Ohio Railroad. This pit is approximately 200 by 300 feet and is about 80 feet deep at the west end where the lowest working encountered a light to orange colored sand.

There is a variation in the section from place to place about the walls. One section measured at the west end is as follows:[1]

Section measured at the west end of "K" pit of Illinois Kaolin Company

	Thickness *Feet*
6. Loess at top	..
5. Gravel	1
4. Sand, white, micaceous; in places stained pink	10
3. Sand, pink to dark purplish red, micaceous	10
2. Clay, pink to red, highly plastic	15
1. Clay, bluish white, highly plastic	15

In some places the entire section is sand, gravel, and loess, while at others clay extends from the gravel to the bottom of the pit. A sketch of the north wall made when the pit was visited in March, 1918, is given in Figure 47. The sand rises as a huge dome and cuts out the clay at its crest over a 40-foot width. Orange sand above is replaced by white with occasional buff below. Discoloration follows the line of contact between the sand and clay. White, purple, buff, and red are mottled in bands due to concentration of underground water circulation along channels of easiest movement. The iron content of the sand and the resultant firmness of cementation increase toward the contact with the clay. Yellow limonite is

[1]St. Clair, Stuart, Clay deposits near Mountain Glen, Union County, Illinois: Ill. State Geol. Survey Bull. 36, p. 13, 1917.

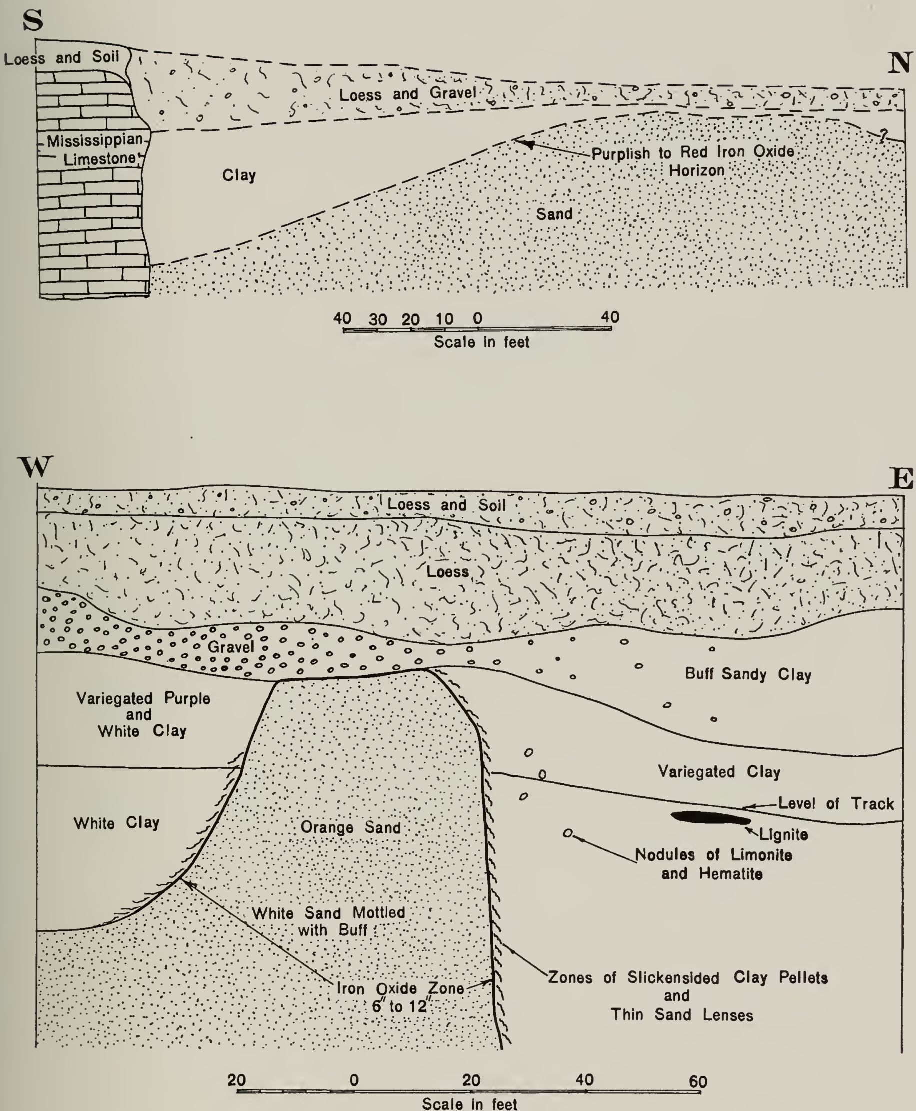


FIG. 47. Diagrammatic sketches of the "K" pit of the Illinois Kaolin Company. Above: North-south profile section. Below: Sketch of the north face.

evident, but Indian red hematite predominates. At each contact zone there is a layer of iron oxides, generally impure from admixtures of sand and clay, though several large hand specimens of pure hematite were broken from these seams. Beyond the contact this iron band grades from hematite through limonite into red, purple, and mottled clay. Concretions of iron oxide may be found 20 feet or more from the contact.

Along this zone of iron, more commonly on the side of the clay, are numerous lenses, pellets, and plate-like stringers of clay with perfect slickensided surfaces and coatings of felty flakes of white mica. Such smoothed zones may be seen out six feet or more from the contact, separated not

FIG. 48. View of the southwest wall of the "K" pit of the Illinois Kaolin Company.

uncommonly by thin sheetings of sand. Lines of weakness extend far beyond these smoothed pellets, as shown in some places by checks in the clay, and in others only upon the weathering of the clay after exposure. Such lines are roughly parallel to the line of contact between the sand and clay. A few larger spalls of clay are caught and completely surrounded by the sand. Rarely is a large quantity of sand included within the clay, but if so included, it is drawn out into a thin flattened stringer bounded on each side by slickensided clay pellets.

These zones have so conspicuous a color when freshly exposed that they stand out and can be traced by the eye from the far side of the pit. The purple iron zone is reported to have been lower in the direction of the

limestone wall at the south and to have everywhere been underlain by sand. This relation of sand to clay, due to a doming of the sand up into and through the clay may explain many of the irregularities found in the clay of the district. Later drilling is reported to have revealed another body of clay with almost vertical walls northwest of the present pit, presumably adjoining the sand dome on the northwest.

Pyrite occurs at certain levels near one edge and a few thin lenses of lignite were found.

Details of the working of this pit and the surrounding property are given by St. Clair in State Geological Survey Bulletin 36 and will be repeated here only briefly. The clay is dug by steam shovel, hauled by small steam engine to a large shed east of the mouth of the pit, cleaned by hand, graded, and stored or loaded directly onto the Mobile and Ohio Railroad switch. Large quantities of clay have been dug and one wall now shows an exposure of 20 feet of variegated, purple and white clay above 35 feet of white and bluish white, highly plastic clay. The greatest overburden is 40 feet with an average of 15 feet or perhaps more.

The southwest wall of the "K" pit is cliff of limestone (fig. 48), and the relation of the clay to this wall suggests that it was deposited in depressions bordered at least partly by the limestone.

Two other pits designated as the "G" and the "F," are located on this same property, north and west of the present "K" pit.

PITS OF THE FRENCH CLAY BLENDING COMPANY

The pit of the French Clay Blending Company in the NW. ¼ sec. 35, T. 11 S., R. 2 W., was not in operation when visited. Judging from former records and from the fact that clay outcrops in a gully not far from the pits, the workings probably represent one of the largest remaining clay deposits of the area. One exposure of bed rock just southeast of the former pit is an unfossiliferous limestone with chert, which dips 14° NE. and strikes N. 28° W.

This clay was mined by shafts and connecting drifts, and by open pits. No sample was obtained.

GOODMAN PIT

Location and Method of Working

The pit owned and operated by Dr. Goodman of Cobden is located in the NW. ¼ sec. 2, T. 12 S., R. 2W. (fig. 49). The clay is obtained from shafts 14 by 14 feet, that are tightly cribbed, sheeted, and intercrossed with strong log braces set in about three feet from each side. When one shaft reaches the bottom of the clay it is abandoned and partly filled with the overburden from the next shaft which is dug so that it adjoins the old one

by half the length of one of its sides. This method recovers all the clay with a minimum working of overburden.

Stripping and digging from an open pit would reduce the cost of production. Prospecting by drill and pits would outline the shape of the deposit and the quantity available, and thus indicate the development justified.

Geology

The log of the working shaft, which was down about 100 feet when visited March, 1918, is as follows:

Fig. 49. View of Dr. Goodman's mine in the NW. ¼ sec. 2, T. 12 S., R. 2 W.

Log of the Goodman shaft in the NW. ¼ sec. 2, T. 12 S., R. 2 W.

Description of strata	Thickness Feet	Depth Feet
Loess	10	10
Gravel	1	11
Sand	2	13
Clay		
Pink clay (Sample No. 27)	27	40
White and pink (Sample No. 28)	30	70
White clay (to bottom of pit) (Sample No. 25)	30+	100
Sand, orange	..	..

The pink clay is reported to have an approximately uniform thickness over the deposit so far as worked. The white clay is increasing in quantity and quality as the pits are driven farther south in the ridge, for accompanying the rise in the upper surface is a lowering of the base. The results of tests made on samples No. 27, No. 28, and No. 25 are given on pages 321-324.

One small pocket of lignite has been found in the white clay and five or six perfectly smoothed and polished pebbles have been taken from the lower levels. The top of the clay rises south under the ridge and the relation to

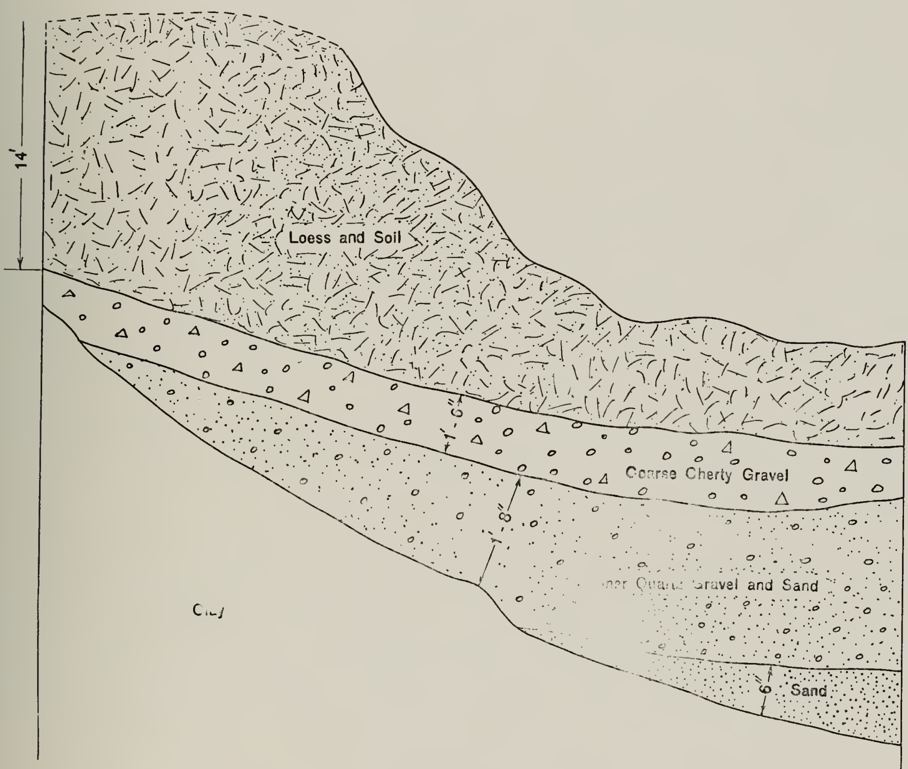


Fig. 50. Sketch made at the mouth of the Goodman shaft.

the sand at the base suggests irregularities similar to those in the Illinois Kaolin Company's pit. A sketch made at the mouth of the shaft (fig. 50) shows the relation of this thickening to the overlying sand and gravel. In addition to the samples noted above, a sample of the "Chocolate" (sample No. 30) clay which is found associated with the white clay was taken, and the results of tests made on it are given on pages 324 and 325.

MINES OF FREDERICK E. BAUSCH

LOCATION AND METHOD OF WORKING

The present Bausch workings include three pits. No. 1 mine, located near the center of sec. 35, T. 11 S., R. 2 W., is reported to have reached a depth of 55 to 60 feet. Tunnels driven from shafts at various levels total 500 feet. The overburden of ten feet has two feet of gravel at the base. The clay is underlain by white sand. Both pyrite and lignite are present commonly occurring together. Pink clay is wanting in this deposit.

At mine No. 2 in the NE. cor. of SW. ¼ sec. 35, T. 11 S., R. 2 W., the section is given as follows:

Section measured at Bausch Mine No. 2 in sec. 35, T. 11 S., R. 2 W.

	Thickness *Feet*
3. Soil	15
2. Sand, reddish, coarse, gravelly (vertical seam)	40
1. Clay, one side of shaft pink, other side, white	25

Mine No. 3 is located in the SE. ¼ sec. 27, T. 11 S., R. 2 W., near the center of the east line of the section, about one mile from the loading stage at Kaolin. The mining is by shaft and tunnels, and the clay is said to be drifting down following the quicksand below. At the present working it is 30 feet thick, with an overburden of about 18½ feet. The clay is assorted and trimmed by hand.

Three grades of clay are made: namely, A1 or No. 3 (sample No. 121), Blue No. 2 (sample No. 122), and No. 1 (sample No. 9); tests were made on these samples with the results given on pages 325 to 327.

GEOLOGY

This pit is located between upthrown Mississippian limestone at the east and the Devonian highlands at the west. The limestone outcrops in a scarp less than 200 yards east of the pit, dips 20° E., and strikes N. 15° W. Drillings by the Illinois Kaolin Company south of this pit near the NE. cor. sec. 34 show only black pyritic Devonian shale. The clay is evidently in an isolated depression.

ELMER GANT MINE

The Gant clay mine is located in the SE. ¼ SE. ¼ sec. 2, T. 12 S., R. 2 W., about 1½ miles by wagon road from the Mobile and Ohio Railroad switch at Kaolin. The clay is mined from a shaft 14 by 14 feet with "lead tunnels." It is drawn out by horse and bucket and the better grades are assorted and trimmed by hand. Three grades are made, pink and white mottled, No. 3 (sample No. 29); white, No. 2 (sample No. 23); and the bluish white, No. 1 (sample No. 26); tests of these samples are reported on pages 327 to 329.

The overburden of loess and gravel is from 6 to 12 feet thick. Several test pits have been dug and borings have been made; one is reported to have gone 73 feet in clay. The present workings are 35 feet deep.

But very small amounts of lignite have been found associated with the clay and no pyrite is reported.

This clay is obtained from a hollow on the west side of a loess-covered ridge. On the opposite side, beds of crystalline Mississippian limestone are found in place and loose slabs extend up to a level which is not far below the top of the clay.

T. P. SIFFORD PIT

A pit opened by T. P. Sifford is located on the Mary A. Walker farm in the SW. ¼ sec. 1, T. 12 S., R. 2W. The overburden does not exceed 15 feet. The present shaft, a double hoist, 15 by 10 feet, has been dug 62 feet deep into 50 feet of clay. A boring, it is said, penetrated 72 feet of clay. White clay is reported to be above and pink below. In one side of the pit a streak of lignite was associated with concretions of pyrite and marcasite.

This pit is little more than a quarter of a mile east of the Gant pit and is separated from it by a high loess-covered ridge and the crystalline limestone mentioned above. A pit 35 feet deep, dug 100 feet south of the shaft, penetrated nothing but orange sand, below the gravel, indicating a condition similar to that found in the Illinois Kaolin Company's pit.

No clay has been shipped from this pit.

MADDOX AND NIXON PIT

The Maddox and Nixon clay mine is located in the NE. ¼ sec. 10, T. 12 S., R 2 W., less than half a mile west of the loading switch on the Mobile and Ohio Railroad. Six 14- by 14-foot cribs have been mined from clay reported to be from 12 to 35 feet thick. The top of the clay rises and the base lowers as the pits are driven farther back into the ridge. Three grades of clay have been obtained: No. 1, blue clay (sample No. 11); No. 2, white clay (sample No. 16); and No. 3, pink and white mottled clay. The best grade comes from the lower parts of the pits. Results of tests made on samples No. 11 and No. 16 are given on pages 329 and 330.

The overburden is about 12 feet thick. White sand underlies the clay.

SMALLER PITS

Much prospecting done outside of the main clay area, has discovered a few small lenses of clay.

Wm. Ferril dug a small amount of sandy clay from pits in the NE. ¼ sec. 3, T. 12 S., R. 2 W. Much sand and gravel accompanies this clay and the quantity is probably small.

Samples No. 18 and No. 22 were taken from this property, and reports on their testing are given on pages 330 and 331. The latter is Ferrill's best or "Blue" clay.

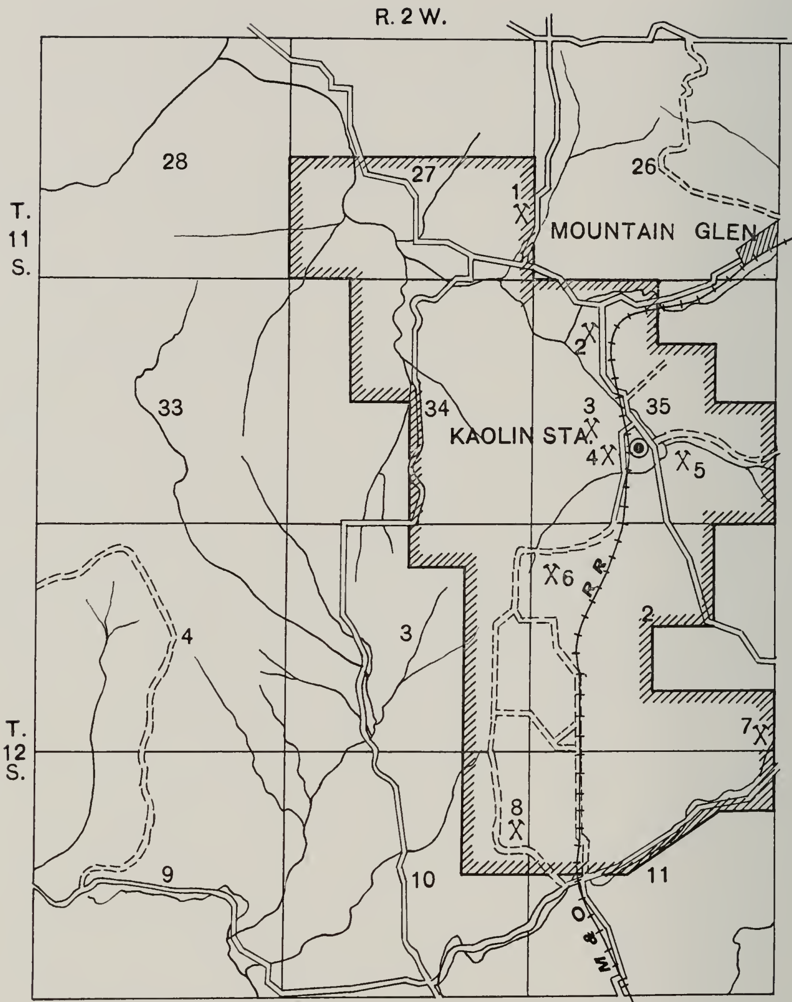


FIG. 51. Map of the Mountain Glen area. The lands known to include deposits of clay having proven or probable commercial value are indicated by shading.

The following list contains the names of the owners of the several pits or mines shown on the above map:

1. Frederick E. Bausch (Mine No. 3)
2. French Clay Blending Company
3. Frederick E. Bausch (Mine No. 2)
4. Illinois Kaolin Company (3 pits)
5. Frederick E. Bausch (Mine No. 1)
6. Dr. Goodman
7. Elmer Gant
8. Maddox and Nixon

Another pit has been opened in the NE. ¼ sec. 17, T. 11 S., R. 2 W., where the clay is sandy and mixed with red surface clay at the top. No clay has been shipped. This is at an elevation of about 625 feet above sea level.

Much other prospecting has been done, and it is hardly likely that there are many deposits of the high grade clay that are not now known. Figure 51 is a map of the Mountain Glen area on which the lands known to include deposits of clay having proven or probable commercial value, are indicated by shading.

COMPARISON WITH THE CLAYS NEAR MAYFIELD, KENTUCKY

Pink and white clay reported to be 30 feet thick is dug on the D. M. Chapman farm 2½ miles west of Hickory, Kentucky. The pink clay is mostly at the top and there is some coloring from lignite. Similar clay is also dug 3 miles west of Hickory, where the average thickness is about 16 feet. These clays are in the lower part of the Wilcox group.

In color, texture, and physical properties these clays resemble the Union County clays of Illinois. The presence of lignite and the lack of stratification is common to both.

COMPARISON WITH THE CLAYS OF LUTESVILLE, MISSOURI

In texture and color the clays of Union County, Illinois, are similar to the kaolin of the Lutesville district, Missouri. Those clays, however, are thought to occupy the same position as the bed rock from which they were derived and are a residual product from the decay of a sedimentary rock, presumably a cherty limestone interbedded with thinner beds of siliceous strata. This decay seems to have been localized along fault planes. In the Bausch mine, two miles west of Glen Allen, a sandstone bed is now represented by three feet of quartzite 30 feet below the top of the shaft. This is interbedded with white kaolin above and below. Traces of former bedding planes are evident in the walls of the mine and irregular seams of chert parallel the bedding and sets of fracture lines. Large numbers of chalcedonic nodules suggest considerable solution, concentration, and redeposition of silica, though part of the siliceous material is still distributed as stringers and beds of granular white "tripoli." In some of the concretionary masses such silica has served as the nucleus of deposition and is now enclosed in a coating of hard, banded chalcedony.

The clay varies from white through grayish-white to reddish pink.

The presence of lignite and an occasional pebble in the Illinois clays is proof of reworking, transportation, and redeposition, or, in other words, of a sedimentary clay in contrast to the similar clay in Missouri which is still residual.

RESULTS OF TESTS

UNION COUNTY, MOUNTAIN GLEN AREA

Samples F, G, and K3

(Illinois Kaolin Company; SW. ¼ sec. 35, T. 11 S., R. 2 W.)

Three samples of clays received from the Illinois Kaolin Company prior to the visit of members of the Survey were tested with the results as shown under the headings F, G, and K3.

		(F)	(G)	(K3)
Water of plasticity	*per cent*	37.4	...	41.4
Shrinkage water	*per cent*	18.9	...	24.0
Pore water	*per cent*	18.5	...	17.4
Modulus of rupture	*lbs. per sq. in.*	142.5	145	195.6
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	259.5	163.7	202.8
Slaking test	*min.*	21	21½	.....

Screen test:—

(Sample F)

Mesh	Residue *Per cent*	Character of residue
20	.13	Silica and particles of coal
40	.10	Quartz particles, some colored with iron
60	.47	Quartz particles, rounded, colored with iron
80	.13	Clear quartz particles
120	3.14	White and brown quartz particles
200	1.4	White quartz particles

(Sample G)

Mesh	Residue *Per cent*	Character of residue
120	.37	White quartz particles
200	.22	Quartz sand

Drying shrinkage:—

	Per cent (F)	(G)	(K3)
Linear; wet length	5.26	5.27	10.0
Linear; dry length	5.68	5.68	11
Volume	28	29	40.2

Burning test:—

(Sample F)

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	19.9	....	9.2	....
5	6.6	Cream	11.0	Hackly fracture
9	3.2	Gray exterior; bluestoned	11.5	
12	3.96	Tan exterior; bluestoned	10.8	
13½	3.68	....	10.6	
15	4.2	Tan exterior; bluestoned	11.0	

(Sample G)

2	25.1	White	5.9	....
5	18	Cream white	8.4	Hackly fracture
9	7.55	Cream	9.2	
12	2.81		9.4	
13	2.57		11.4	
15	3.26	Tan exterior; bluestoned	11.1	Hackly fracture; veining of fine cracks in the surface

(Sample K³)

04	34	Cream white	4.3	Hackly fracture
02	33	Cream white	4.8	
2	20	Cream white	...	
5	21	Cream white	9.0	
9	7	Cream white	12.0	
13	3	Gray white; bluestoned	...	Fine-meshed surface cracks
14	3	Tan exterior; bluestoned	13.0	

	(F)	(G)	(K³)
Fusion test	....	Cone 29/30	Cone 32

Summary

Samples F, G, and K³ are all similar in appearance, excepting for the slight differences in color. In plasticity and working properties there is little difference. They are all similar in having a higher strength when mixed with standard sand than when tested as pure clay. The bonding strengths of K³ and F are medium. G is low. The amount of residue left on the various sizes of screen mesh is exceedingly small. The drying shrinkage of K³ is medium high while that of F and G is medium low. The burning shrinkages at cone 9 are high for all three samples. The sample F is well vitrified at cone 9, while the other samples are slightly less so at the same temperature. These are refractory clays, which do not overburn at cone 15.

These clays belong to a class which has been found very useful for admixture with others in the production of close burning refractory bodies; also of bodies not of refractory nature but of close texture or having a high content of non-plastic material which must be well bonded together.

Sample No. 27

(Goodman pit; NW. ¼ sec. 2, T. 12 S., R. 2 W.)

This is a soft pinkish-colored clay, varying somewhat in shade and showing an occasional yellowish streak. The working properties of the plastic mass are good It flows through a die satisfactorily when in a stiff condition.

Water of plasticity	*per cent*	36.4
Shrinkage water	*per cent*	8.2
Pore water	*per cent*	28.2
Modulus of rupture	*lbs. per sq. in.*	265
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	120.9
Slaking test, average	*min.*	20

Screen test:—

Mesh	Residue *Per cent*	Character of residue
120	.015	Fine sand
150	.57	Sand
200	.63	Sand

Drying shrinkage:—

	Per cent
Linear; wet length	6.7
Linear; dry length	7.38
Volume	29.4

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	23	Pink	9.57	.....
5	14	Pink	10.85	Hackly fracture
9	2.6	Light tan; bluestoned	12.0	Hackly fracture
12	1.6	Light tan exterior; heavily bluestoned	.....	.....
13½	7	Light tan exterior; heavily bluestoned	9.27	.....
15	6.24	Dark buff; bluestoned	10.4	Fine mesh of cracks

Fusion test:—It deforms at 29/30 cone.

Summary

The strength of the unburned clay is medium. The bonding strength is medium low. The percentage of residues left on the screens is slight. The drying shrinkage is medium. The total shrinkage at cone 9 is medium high. Vitrification is complete at cone 12. The apparent overburning at cone 13½ may be due to the development of small cracks in the test piece during the firing since there is no further increase in the porosity at cone 15. It is a refractory clay. This clay is adapted for use in the manufacture of refractories, especially those which burn densely. This clay burns to a very dark color for a fire clay.

Sample No. 28

(Goodman pit; NW. ¼ sec. 2, T. 12 S., R. 2 W.)

This is a soft clay varying in color from cream to red. The plastic mass is readily molded. It flows poorly through the die.

Water of plasticity	*per cent*	38.3
Shrinkage water	*per cent*	18.7
Pore water	*per cent*	19.5
Modulus of rupture	*lbs. per sq. in.*	192.7
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	151.8
Slaking test, average	*min.*	10.5

Drying shrinkage:—

	Per cent
Linear; wet length	7.45
Linear; dry length	8
Volume	30.9

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
01	30	Pinkish white	7.42	....
3	16	Light cream	11.1	....
4	10.1	Light cream	11.7	....
6	7	Cream	12.0	Hackly fracture
9	3.0	Cream; bluestoned	12.9	Vitreous; hackly fracture
12	2.5	Gray; bluestoned	13.5	Vitreous; hackly fracture
13	3.4	Cream; bluestoned	13.6	Vitreous; hackly fracture
15	4.7	Tan exterior; bluestoned	13.4	Hackly fracture. Fine veining of cracks throughout test piece

Soluble salts:—Pieces burned at the low cones show strongly characteristic yellowish surface coating after soaking in water.

Fusion test:—It deforms at cones 32/33.

Summary

This clay has a medium low strength in the unburned condition. Its bonding strength is low. The absence of residues on the screens indicates a very fine-grained material. The drying shrinkage is medium. The total shrinkage at cone 9 is high. Vitrification is nearly complete at cone 12. The clay is highly refractory and is especially adapted to the manufacture of such wares, especially those which should burn dense at a low temperature.

Sample No. 25

(Goodman pit; NW. ¼ sec. 2, T. 12 S., R. 2 W.)

This is a white clay which shows a few reddish stains on the faces of fractures. Its working properties in the plastic condition are good. When the clay is in a stiff consistency it flows satisfactorily through a die.

Water of plasticity	*per cent*	39.5
Shrinkage water	*per cent*	19.4
Pore water	*per cent*	20
Modulus of rupture	*lbs. per sq. in.*	131.2
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	141.4
Slaking test, average	*min.*	12

Drying shrinkage:—

	Per cent
Linear; wet length	8.3
Linear; dry length	9.1
Volume	32

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	23.7	Cream	8.45	....
5	20	Cream	9.15	Hackly fracture
9	3.6	Gray; bluestoned	10.9	Hackly fracture
12	0.7	Gray; bluestoned	11.9	Hackly fracture
13½	0.9	....	12.5	Hackly fracture
15	3.0	Gray exterior; bluestoned	11.8	Hackly fracture

Fusion test:—It deforms at cone 32.

Summary

The strength of the unburned clay is medium low. Its bonding strength is medium low. Practically no residues are retained on the screens. The drying shrinkage is medium. The total burning shrinkage at cone 9 is high. Vitrification is complete at cone 12. Overburning seems to be indicated at cone 15. It is quite possible that this appearance is due to the peculiar cracking of the piece rather than a real vesicular structure. It is a refractory clay. It is suggested that it will find important uses in the manufacture of refractories, especially those requiring a dense structure.

Sample No. 30

(Goodman pit; NW. ¼ sec. 2, T. 12 S., R. 2 W.)

This is a soft clay of a cream color, shading into reddish. Its working properties in the plastic condition are good. It flows satisfactorily through a die when it has a stiff consistency.

Water of plasticity	*per cent*	44.2
Shrinkage water	*per cent*	21.4
Pore water	*per cent*	22.8
Modulus of rupture	*lbs. per sq. in.*	345
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	229.4
Slaking test	*min.*	13

Screen test:—

Mesh	Residue *Per cent*	Character of residue
120	1.46	Cream-colored sand
150	0.39	Cream-colored sand
200	0.24	Very fine sand

Drying shrinkage:—

	Per cent
Linear; wet length	7.5
Linear; dry length	8.25
Volume	34.6

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	25.7	Cream	12.3	....
5	1.3	Gray	13.7	Hackly vitreous fracture
9	3.7	....	13.0	
12	3.2	Tan exterior; bluestoned interior	13.2	
13	0.1	....	12.4	
15	5.3	Buff; bluestoned	11.4	Hackly vitreous fracture. Surface covered with mesh due to cracks

Soluble salts:—Piece burned at cone 2 after soaking in water shows greenish-yellow surface coating. Possibly vanadium salts.

Fusion test:—It fused at cone 32.

Summary

The strength of the unburned clay is medium. Its bonding strength is medium. The percentage of residues is slight. The drying shrinkage is medium. The total

shrinkage at cone 9 is high. Practically complete vitrification is reached at cone 5 and overburning is slight if any at cone 15.

Suggested uses: Refractories, particularly crucibles and glass pots, etc.; architectural terra cotta, sanitary ware, stoneware.

Sample No. 121

(Frederick E. Bausch mines; near Mountain Glen)

This is a soft white clay. When tempered with water, it becomes very plastic and inclined to be sticky. It flows very poorly through the die.

Water of plasticity	*per cent*	37.1
Shrinkage water	*per cent*	20.9
Pore water	*per cent*	16.2
Modulus of rupture	*lbs. per sq. in.*	191
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	123.3
Slaking test, average	*min.*	22+

Screen test:—

Mesh	Residue *Per cent*	Character of residue
60	Trace	Sand
80	Trace	....
120	.09	Fine white sand
200	.24	White sand and mica

Drying shrinkage:—

	Per cent
Linear; wet length	7.4
Linear; dry length	8.2
Volume	33.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	18.3	Cream white	8.3	Hackly fracture
5½	13.0	Cream white	8.8	Hackly vitreous fracture
9	1.68	Gray; bluestoned	9.6	
12	1.40	Gray; bluestoned	10.3	
13½	2.0	Gray; bluestoned	9.8	
15	2.5	Gray exterior; bluestoned	9.3	

Fusion test:—It deforms at cone 30.

Summary

The clay has a medium low strength and medium low bonding strength. The amount of screen residues is negligible. The drying shrinkage is medium. The total shrinkage at cone 9 is high. Vitrification is practically complete at cone 9 and the clay is not overburned at cone 15. The clay is refractory.

This is the type of clay which is useful in the manufacture of dense burning refractories.

Sample No. 122

(Frederick E. Bausch mines; near Mountain Glen)

This is a soft white clay which becomes very plastic when tempered with water. It is also somewhat sticky. It flows badly when forced through a die.

Water of plasticity	*per cent*	37.9
Shrinkage water	*per cent*	20.6
Pore water	*per cent*	17.3
Modulus of rupture	*lbs. per sq. in.*	177.0
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	136.5
Slaking test, average	*min.*	29+

Screen test:—

Mesh	Residue *Per cent*	Character of residue
120	.25	White sand
200	.10	White sand

Drying shrinkage:—

	Per cent
Linear; wet length	7.4
Linear; dry length	7.8
Volume	35

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	20.0	Cream white	8.0	......
3	13.3	Cream white	....	Cracked along lines of differential flow
6	10.0	Darker cream white	....	Hackly fracture
9	1.3	Gray; bluestoned	....	
12	2.8	Gray	9.7	
13½	2.4	Gray	10.4	
15	3.3	Gray to tan exterior; bluestoned	10.2	

Fusion test:—Down at cone 32. Not vesicular.

Summary

The strength of this clay with and without the addition of standard sand is medium low. It has a very fine texture, leaving hardly more than a trace of residue upon the screens. The drying shrinkage is medium and the total shrinkage at cone 9 is high. Vitrification is practically complete at cone 9 and the slight increases in porosity at the higher cones is apparently due to the formation of fine cracks which permeate the mass, rather than due to overburning. It is a refractory clay.

Suggested Uses: This clay belongs to the type of refractory clays which is of importance in the preparation of refractory wares having a dense structure. It is also similar to the architectural terra cotta and stoneware clays, although it is doubtful that it could be used alone to advantage for the latter purpose.

Sample No. 9

(Frederick E. Bausch mines; near Mountain Glen)

This is a soft clay of a pink color with streaks of brownish yellow and red. Its working property is fair, and it is rather sticky. Its conduct when flowing through a die is fair

Water of plasticity	*per cent*	32.7
Shrinkage water	*per cent*	23.5
Pore water	*per cent*	9.2
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	104.4
Slaking test, average	*min.*	19

Fusion test:—It deforms at cone 31.

Summary

This clay is slightly more refractory than Nos. 121 and 122 but similar to them in its properties in both the unburned and the burned condition.

Sample No. 29

(Elmer Gant mine; SE. ¼ SE ¼ sec. 2, T. 12 S., R. 2 W.)

This is a soft white clay, marked by a few yellow and a few black veins. Some of the pieces are of a pronounced yellowish color. Its working properties in the plastic condition are good except that it is somewhat sticky. Its conduct when flowing through a die is fair.

Water of plasticity	*per cent*	35.8
Shrinkage water	*per cent*	18.7
Pore water	*per cent*	17.1
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	286.12
Slaking test, average	*min.*	16

Screen test:—

Mesh	Residue *Per cent*	Character of residue
120	0.45	White sand
200	0.23	White sand

Drying shrinkage:—

	Per cent
Linear; dry length	6.2
Linear; wet length	5.75
Volume	20.4

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
1	20.4	Light cream	7.4	Hackly fracture
2½	11.3	Light cream	9.6	
3	10.6	Light cream	9.6	
6	2.3	Cream	10.0	
8½	2.0	Cream; slightly bluestoned	....	
9	2.1	Cream; slightly bluestoned	....	
12	1.9	Cream; bluestoned	11.0	
13	2.2	Cream; bluestoned	11.0	
15	3.0	Tan exterior; bluestoned	9.6	

Fusion test:—It deforms between cones 32 and 33.

Summary

This clay has medium strength. The percentage of residue is slight. The drying shrinkage is medium. The total shrinkage at cone 12 is medium high. Vitrification is nearly complete at cone 6. Suggested uses are refractories, especially for crucibles and other dense wares, architectural terra cotta, stoneware, sanitary ware.

Sample No. 23

(Elmer Gant mine; SE. ¼ SE. ¼ sec. 2, T. 12 S., R. 2 W.)

This is a white soft clay which has some veins of red through it. Its working properties in the plastic condition are good. It flows fairly well through a die.

Water of plasticity	*per cent*	35.8
Shrinkage water	*per cent*	19.2
Pore water	*per cent*	16.6

Modulus of rupture .... *lbs. per sq. in.* 311.2
With 50% standard sand—Modulus of rupture .... *lbs. per sq. in.* 302.3
Slaking test, average .... *min.* 23

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	Trace	....
40	Trace	....
60	Trace	....
120	0.2	White sand
200	0.43	White sand

Drying shrinkage:—

	Per cent
Linear; dry length	7.7
Linear; wet length	7.1
Volume	32.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	12.1	Cream white	10.0	....
3	4.8	Cream white	9.0	....
6	2.6	Cream; bluestoned	9.5	Hackly vitreous fracture
9	2.4	Cream; bluestoned	10.0	Vitreous fracture
12	2.9	Bluestoned	10.0	Vitreous fracture
13	1.1	Light tan exterior; bluestoned	.....	Vitreous fracture
15	2.0	Tan exterior; bluestoned	10.0	Fine closed cracks on the surface

Fusion test:—It deformed at cone 32.

Summary

The strength of the unburned clay is medium. Its bonding strength is medium. The percentage of screen residues is slight. The drying shrinkage is medium. The total shrinkage at cone 9 is high. Vitrification is complete at cone 13. It is a refractory clay. It is suggested that it will be found of use in the manufacture of refractories requiring a densely burned body at a low temperature, such as crucibles.

Sample No. 26

(Elmer Gant mine; SE. ¼ SE. ¼ sec. 2, T. 12 S., R. 2 W.)

This is a soft white clay which may be brought to a good plastic condition with the development of some stickiness. It flows through a die satisfactorily when it is in a stiff condition.

Water of plasticity .... *per cent* 41.5
Shrinkage water .... *per cent* 25
Pore water .... *per cent* 16.5
Modulus of rupture .... *lbs. per sq. in.* 259.0
With 50% standard sand—Modulus of rupture .... *lbs. per sq. in.* 137.5
Slaking test, average .... *min.* 34

Drying shrinkage:—

	Per cent
Linear; dry length	8.4
Linear; wet length	7.64

Burning test:—

Cone	Porosity	Color	Burning shrinkage	Remarks
	Per cent		*Per cent*	
2	16	....	10.2	....
5	1.4	Gray white	10.7	Hackly, vitreous fracture
9	1.8	Stoneware gray	11.3	Hackly, vitreous fracture
12	2.8	Light tan exterior; heavily bluestoned	11.0	Hackly, vitreous fracture
13	3.27	....	10.0	Hackly, vitreous fracture
15	3.0	Gray exterior; bluestoned......	9.1	Hackly fracture

Fusion test:—It deformed at cone 33.

Summary

The strength of the unburned clay in the dry condition is medium. The bonding strength is medium low. It leaves no residues on the screens. The drying shrinkage is medium. The total shrinkage at cone 9 is high. Vitrification is practically complete at cone 5. It is highly refractory clay. It is suggested that it will find use in the manufacture of refractories, especially those having a dense body.

Sample No. 11

(Maddox and Nixon mine; NE. ¼ sec. 10, T. 12 S., R. 2 W.)

This is a plastic clay of a white color. It has good working properties and flows through a die quite satisfactorily.

Water of plasticity	*per cent*	32.9
Shrinkage water	*per cent*	23.5
Pore water	*per cent*	9.3
Modulus of rupture	*lbs. per sq. in.*	43.4 (?)
Slaking test, average	*min.*	6

Screen test:—

Mesh	Residue *Per cent*	Character of residue
40	None	....
60	0.03	White sand
80	0.03	White sand
120	0.8	White sand, some mica
200	2.1	White sand, some mica

Drying shrinkage, linear; dry length..................................*per cent* 4.5

Burning test:—

Cone	Porosity	Color	Burning shrinkage	Total shrinkage
	Per cent		*Per cent*	*Per cent*
02	39.6	Light cream	3.8	8.3
1	38.4	Light cream	4.5	9.0
3	31.1	Light cream	7.4	11.9
5	28.8	Dark cream	9.0	13.5
7	15.6	Dark cream	9.9	14.4
9	12.9	Light brown	11.2	15.7
13	6.9	Light brown	....	....

Fusion test:—It deforms at cone 33.

Summary

The percentage of screen residues is slight. The drying shrinkage is medium low. The total shrinkage at cone 9 is high. Vitrification is incomplete even at cone 13. It is a highly refractory clay. It is suggested that it will find use in the manufacture of refractories of a high grade.

Sample No. 16

(Maddox and Nixon mine; NE. ¼ sec. 10, T. 12 S., R. 2 W.)

This is a soft clay of nearly white color. Its working property is good. Its conduct when flowing through a die is satisfactory.

Water of plasticity	*per cent*	28.3
Shrinkage water	*per cent*	10.8
Pore water	*per cent*	17.5
Modulus of rupture	*lbs. per sq. in.*	64.1
Slaking test, average	*min.*	10.5

Screen test:—

Mesh	Residue *Per cent*	Character of residue
60	0.05	White mica and white sand
80	0.22	White mica and white sand
120	5.3	White sand
200	5.4	White sand

Drying shrinkage, linear; dry length	*per cent*	4.3
Volume	*per cent*	17.8

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Total shrinkage *Per cent*	
02	35.7	Light cream	2.1	6.4	
1	35.2	Light cream	2.1	6.4	
3	32.2	Light cream	3.3	7.6	Conchoidal Fracture
5	20.4	Light cream	7.4	11.7	
7	19.6	Light cream	8.0	12.3	
9	17.8	Light cream	9.2	13.5	
13	13.0	Dark gray	9.7	14.0	

Fusion test:—It fused at cones 30/31.

Summary

The strength of this clay is low. The percentage of screen residues is considerable. Its drying shrinkage is low. The total shrinkage at cone 9 is medium high. It is not completely vitrified even at cone 13. This is a refractory clay and it will be found useful in the manufacture of refractories.

Sample No. 18

(Wm. Ferril pit; NE. ¼ sec. 3, T. 12 S., R. 2 W.)

This is a soft white clay with occasional yellow discolorations. Its working property is good. It flows satisfactorily through a die.

Water of plasticity	*per cent*	33.2
Shrinkage water	*per cent*	8.9

Pore water .... *per cent* 24.6

Modulus of rupture:—The test pieces prepared for the determination of its strength proved to be too weak to be tested.

Slaking test, average.. *min.* 6

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	None	....
40	Trace	....
60	.04	Fine white sand
80	0.2	Fine white sand
120	0.7	Fine white sand
200	0.9	Fine white sand

Drying shrinkage, linear .... *per cent* 3.1

Volume .... *per cent* 12.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Total shrinkage *Per cent*	Remarks
02	40.9	White	1.9	5.0	....
3	38.6	White	5.6	8.7	....
5	36.3	White	6.2	9.3	....
9	29.1	White	9.0	12.1	....
13	0.05	White	...	....	Contains very fine reddish specks

Fusion test:—It deforms at cone 33/34.

Summary

The strength of the clay is very low. The percentage of screen residues is slight. Its drying shrinkage is medium low. The total shrinkage at cone 9 is medium. Vitrification is incomplete even at cone 13. It is a highly refractory clay. It is suggested that this clay will prove to be of value when used with stronger clays in the manufacture of high grade refractories.

Sample No. 22

(Wm. Ferril pit; N.E. ¼ sec. 3, T. 12 S., R. 2 W.)

This is a moderately hard clay of a light gray color. It has good working properties in the plastic condition and flows satisfactorily through a die.

Since only a small sample was secured for the preliminary test and subsequent attempts to obtain more material were unsuccessful because the face of the pit was inaccessible, complete test could not be made.

The fairly long period required for slaking may indicate a clay of high bonding strength. The fusion test is very satisfactory.

Suggested uses: This clay will be of value in the manufacture of refractories and possibly of particular interest to manufacturers of crucibles.

Slaking test, average .... *min.* 42

Fusion test:—It fuses at cone 32.

MASSAC COUNTY

PADUCAH POTTERY COMPANY'S PIT

The Paducah Pottery Company has a clay pit on the east side of the Chicago, Burlington and Quincy Railroad half a mile north of Choat, in the NE. cor. sec. 17, T. 15 S., R. 4 E. The clay body is lens-shaped and the accompanying sketch (fig. 52) shows the relation to the sandstone and gravel above and the sandstone below. The grayish-white laminated clay is 14 feet 4 inches thick, and 2 feet 10 inches of reddish brown clay above are discarded with the overburden. The clay is loaded at Choat and shipped to the plant at Paducah.

No tests have been made to determine the extent of the clay.

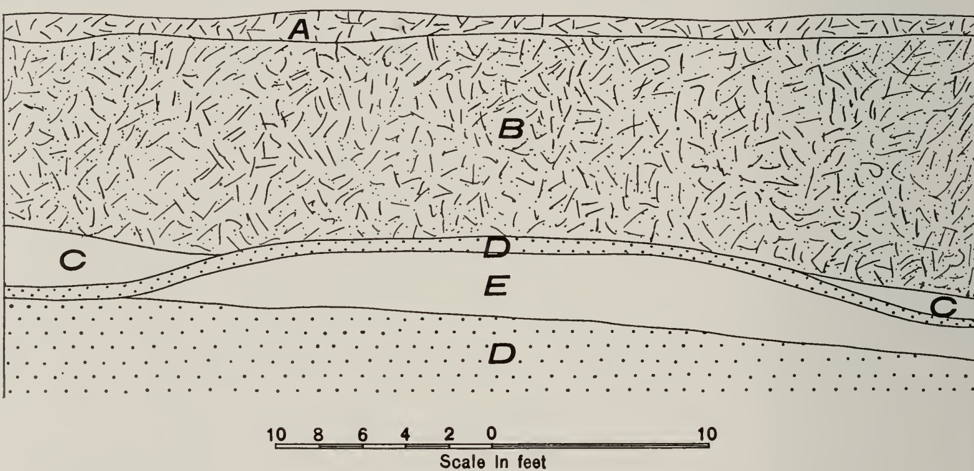


Fig. 52. Sketch showing the clay body and its relations to the surrounding strata at the Paducah Pottery Company's clay pit north of Choat.

A Soil.
B Loess.
C Chert pebbles, red clay, and quartz gravels.
D Sandstone, cemented by iron.
E White clay, laminated with thin sheets of fine micaceous sand.

Shipments vary somewhat as the clay is needed at the pottery, but averaged in the spring of 1918 from one to two cars per week.

CLAYS FROM THE VICINITY OF ROUND KNOB

No clay is dug near Round Knob at the present time, though formerly clay was shipped to potteries at Metropolis and Paducah, and there is an abandoned pit a quarter mile south of Round Knob, in the SW. ¼ sec. 1, T. 15 S., R. 4 E. When operated this pit furnished three grades of clay,

white, blue, and gray, and had a working face of 8 to 10 feet.[1] Another pit nearby had 7 feet of clay. The overburden varied in thickness up to a maximum of 18 feet. Clay could still be obtained by removing a heavy overburden.

A sample was taken from the road gutter a half mile west of Round Knob, in the N. ½ SW. ¼ sec. 8, T. 15 S., R. 4 E., where the section is as follows:

Section half a mile west of Round Knob

	Thickness *Feet*
4. Gravel, rises with the hill	2 to 6
3. Clay, red	4
2. Clay, white and pink, sandy, laminated; stains of iron oxide (sample No. 46)	6½
1. Sand, red and white	1½

A report of the tests made on sample No. 46 is given on pages 333 and 334.

CLAY FROM THE OBERMARK PROPERTY

A well is reported to have penetrated 30 feet of clay on the C. G. F. Obermark farm in sec. 36, T. 14 S., R. 5 E. A thin sandy horizon lies about 4 feet below the surface and streaks of iron at other horizons. The clay is blue-gray, sandy, and of fair plasticity. The sample (Sample No. 47) was taken by boring in a creek bed. Ten acres or more of this clay is available under an overburden of not more than 6 feet. Similar clay has also been dug in sec. 6, T. 15 S., R. 5 E.

A sample (Sample No. 48) was taken from clay exposed along the road between secs. 8 and 9, T. 15 S., R. 6 E. This is an ash-colored, sandy, laminated clay, interbedded with seams of limonite and probably not of commercial value. These two samples (No. 47 and No. 48) were tested with the results given on pages 334 and 335.

RESULTS OF TESTS

MASSAC COUNTY

Sample No. 46

(N. ½ SW. ¼ sec. 8, T. 15 S., R. 4 E.)

This is a soft, very sandy clay, containing much mica. It is a cream color, mottled with brown and pink. When mixed with sufficient water, it develops a fair degree of plasticity and will flow through a die satisfactorily.

Water of plasticity	*per cent*	22.2
Shrinkage water	*per cent*	11.6
Pore water	*per cent*	10.6
Modulus of rupture	*lbs. per sq. in.*	217.4
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	214.0
Slaking test, average	*min.*	27

[1]Purdy, R. C., and DeWolf, F. W., Preliminary Investigations of Illinois Fire Clay: Ill. State Geol. Survey Bull. 4, p. 149, 1907. See description of sample D28.

Screen test:—

Mesh	Residue *Per cent*	Character of Residue
20	Trace	Pyrites, sandstone and mica
40	Trace	Pyrites, sandstone and mica
60	2.9	Mica and sand
80	1.7	White sand
120	36.2	White sand
150	13.5	White sand
200	5.9	White sand

Drying shrinkage, linear ... *per cent* 2.9

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
08	36.7	Light brownish red	+0.5	The clay expands during burning
06	35.4	Light brownish red	+0.6	
04	35	Light brownish red	+0.8	
02	36.8	Light brownish red	+0.6	
1	34.9	Light brownish red	+0.8	
3	36.5	Light brownish red	+0.6	The burned pieces are very weak
5	36.3	Darker brownish red	+0.5	
7	35.3	Darker with iron specks	+1.0	
9	36.0	Darker with iron specks	+0.7	
11	35.5	Darker with iron specks	+0.9	

Fusion test:—It deformed at cone 31.

Summary

This is a clay of medium strength, much higher than might be expected considering its very sandy character. The bonding strength is medium. The percentages of screen residues are high. The drying shrinkage is low. Because of its sandy nature, the clay has a high and nearly constant porosity at all temperatures showing no sign of vitrification. This also explains the reason for the fact that it does not shrink but expands slightly at all temperatures.

Suggested uses: The lack of strength of the unburned clay will restrict its usefulness to admixtures with other clays. Such sandy clays often have a distinct usefulness. Because of its high fusion test it should be of use in refractories.

Sample No. 47

(C. G. F Obermark farm; sec. 36, T. 14 S., R. 5 E.)

This is a dark colored, moderately hard clay. It has a medium plasticity when mixed with 28.5% water and in that condition shows rather poor flowing properties when squeezed through a die.

Water of plasticity ... *per cent* 25.3
Shrinkage water ... *per cent* 16.0
Pore water ... *per cent* 9.3
Modulus of rupture ... *lbs. per sq. in.* 365.8
Slaking test, average ... *min.* 10
Drying shrinkage, linear ... *per cent* 6.8

Burning test:—

Cone	Porosity	Color	Burning shrinkage	Total shrinkage	Remarks
	Per cent		*Per cent*	*Per cent*	
02	20.6	Dark cream	3.2	10.0	....
1	20.9	Dark cream	3.2	10.0	....
3	19.6	Cream	3.2	10.0	....
7	13.9	Gray	3.4	10.2	Conchoidal fracture
9	7.6	Gray	4.4	11.2	....
10	9.5	Gray	...	....	No evidence of over-burning

Fusion test:—Completely deformed and vesicular at cone 27.

Summary

This clay has a medium strength and medium drying shrinkage. The burning shrinkage at cone 9 is low. It is an open burning clay, which is incompletely vitrified at cone 10. The clay is not refractory.

Suggested uses: Face brick, stoneware, architectural terra cotta, sanitary ware.

Sample No. 48

(Secs. 8 and 9, T. 15 S., R. 6 E.)

This is a gray colored clay, mottled with brown. It contains much mica.

Slaking test, average .... *min.* 12.5

Fusion test:—No deformation at cone 27.

Summary

Insufficient material was received for complete test. However, it was found to be a refractory clay. The mode of occurrence with seams of limonite will prevent its use unless some method of purification is employed.

PULASKI COUNTY

CLAYS FROM THE VICINITY OF GRAND CHAIN

Clay was formerly dug for pottery near Grand Chain Landing and recently prospect pits have been opened at several places.

On the O. C. Field property pits have been dug in lenses of clay in the NE. ¼ sec. 9, T. 15 S., R 2 E., where sample No. 38, tests of which are reported on pages 336 and 337, was taken. Both the bottom and the top are irregular, the top rising backward into the hill. A thickness of 20 feet of "black fat" clay has been exposed and is said to be underlain by blue and pink clay. The overburden of 3 feet of iron-cemented sand and gravel capped by loess thickens back over the ridge to a maximum of 15 feet. Clay has also been worked just above water level in Ohio River.

J. W. Joynt of Tamms, Illinois, has done considerable prospecting both by boring and pits in east half of sec. 4 and west half of sec. 3, T. 15 S., R. 2 E.

The clay is irregular and lenticular, ranging up to 12 feet as a maximum thickness. It is underlain by sand and overlain by gravel and loess. At pits in the N. ½ SE. ¼ sec. 4 the overburden will average 14 to 15 feet. This clay is white and resembles the clay from Mountain Glen. Clay from

the J. B. Hays farm in the SW. ¼ sec. 3 was of a chocolate color and contained lignite. The sample No. 37 was taken from a bin which contained clay from several test pits. Results of tests made are reported on pages 337 and 338.

A sample of white to gray plastic clay was taken from the road ditch two miles east of Grand Chain, where clay was in the gutter. The sample was obtained by boring. The section is as follows:

Section 2 miles east of Grand Chain

	Thickness Ft.	In.
4. Loess	16 to 32	...
3. Gravel and red clay	4	6
2. Clay, red	1±	...
1. Clay, white to gray, plastic; exposed in road gutter	21	4

Sample No. 45 resampled as No. 1678 represents the upper portion. Sample No. 44 resampled as No. 1691 is from the lower portion of the deposit. Results of tests made on these two samples are presented on pages 338 to 340.

The top surface of the clay probably rises in the hill and if so the overburden would be less than given in the section. Other slopes show sand and impure clay at this horizon, proving that the clay is lenticular just as it is at other localities.

CLAY FROM CALEDONIA

A sample, No. 17, was taken from the dark gray clay exposed along the river bank at Caledonia (nearest railroad station, Olmsted). This comes from a 25-foot exposure and is a weathered product of the "soapstone" of Midway age.

The lower 14 feet of a section exposed in the river bluffs on the Barber farm, 2½ miles above Caledonia, in sec. 13, T. 15 S., R. 1 E., is of a gray, micaceous, thinly bedded clay. This contains some lignite and pyrite concretions and is said to extend down to low water level 20 feet below the bottom of the measured section. The overburden would be very thick, but hydraulic stripping would be possible at this place. Sample No. 37a (see page 341 for results of tests) is from this horizon. A very plastic white clay is exposed about 200 yards down stream at or near the water level. The exposure is small and the quantity uncertain.

RESULTS OF TESTS

PULASKI COUNTY

Sample No. 38

(O. C. Field pit; NE. ¼ sec. 9, T. 15 S., R. 2 E.)

This is a soft shaly material of a brownish color. It has good plasticity and flows smoothly through the die when a suitable amount of water is added.

Water of plasticity	per cent	38.6
Shrinkage water	per cent	24.6
Pore water	per cent	14.0
Modulus of rupture	lbs. per sq. in.	164.8
Slaking test	min.	50

Screen test:—

Mesh	Residue *Per cent*	Character of Residue
20	0.27	Rock particles
40	0.25	Rock particles and sand
80	0.16	Rock particles and sand
120	1.69	Rock particles and sand
200	1.52	Rock particles and sand

Drying shrinkage:—

	Per cent
Linear; wet length	7.25
Linear; dry length	7.8

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
04	33.4	White	1.8	....
02	24.7	Cream	3.4	Hackly fracture
2	18.1	Cream	6.0	....
5	16.5	Cream	5.6	Hackly fracture
9	14.0	Cream	6.0	Hackly fracture, vitreous
13	3.7	Stoneware gray	7.0	Smooth fracture
14	2.8	Dark buff exterior, bluestoned	6.2	Appears to be overburned

Fusion test:—It deforms at cone 30.

Summary

The dry clay has medium low strength. The amount of residues left on the screens is low. The drying shrinkage is medium. The total shrinkage at cone 9 is medium high. Vitrification is practically complete at cone 13. It is a refractory clay and therefore suitable for use in the manufacture of such wares. The light color of the burned clay and its other properties make it available for architectural terra cotta, stoneware, and sanitary ware.

Sample No. 37

(Secs. 3 and 4, T. 15 S., R. 2 E.)

This is a soft clay containing a few nodules of carbonaceous matter. It is of a light gray color. It flows through a die fairly satisfactorily.

Water of plasticity	per cent	30
Shrinkage water	per cent	21.6
Pore water	per cent	8.4
Modulus of rupture	lbs. per sq. in.	487.2
With 50% standard sand—Modulus of rupture	lbs. per sq. in.	249.7
Slaking test. average	min.	7

Screen test:—

Mesh	Residue *Per cent*	Character of Residue
20	Trace	....
40	Trace	....
60	Trace	....
80	Trace	....
120	.02	Quartz and mica particles
200	.07	Quartz and mica particles

Drying shrinkage:—

	Per cent
Linear; wet length	6.6
Linear; dry length	7.1

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	15.9	Cream	4.95	....
5	9.6	Darker cream	5.7	....
9	1.7	Gray	10.1?	Conchoidal vitreous fracture
12	.57	....	5.6	Conchoidal vitreous fracture
13½	18	Tan exterior; bluestoned interior	4.34	

Fusion test:—It deformed at cone 28.

Summary

The strength of the unburned clay is medium high. Its bonding strength is medium. There is only a trace of residues on the screens. The drying shrinkage is medium. The total shrinkage at cone 9 is high. Vitrification is practically complete at cone 9. The sample is apparently overburned at cone 13½ although it is thought this appearance may be due to the peculiar shattering of the clay during the firing. It is a refractory clay.

Suggested uses: For refractories, particularly those of a dense character such as crucibles; also architectural terra cotta, stoneware, and sanitary ware.

Sample No. 45 (resampled as No. 1678)

(2 miles east of Grand Chain)

This clay was bored for samples and later resampled as No. 1678. This record applies to sample No. 1678.

It is a clay of medium hardness and a red color. It develops a good plasticity when worked with the addition of a sufficient amount of water. When the plastic clay is squeezed through a die it flows fairly well.

Water of plasticity	*per cent*	29.2
Shrinkage water	*per cent*	15.8
Pore water	*per cent*	13.4
Modulus of rupture	*lbs. per sq. in.*	526.6
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	299.5
Slaking test	*hours*	2½

Screen test:—

Mesh	Residue Per cent	Character of residue
20	1.0	Brown sandstone
40	Trace	Mica and white sand
60	Trace	Mica and white sand
80	Trace	Mica and white sand
120	30.2	Brown and white sand
150	9.4	Brown and white sand
200	2.0	Brown and white sand

Drying shrinkage, linear .... *per cent* 6.8

Burning test:—

Cone	Porosity Per cent	Color	Burning shrinkage Per cent
08	36.8	Reddish brown	0.6
06	35.0	Reddish brown	1.1
04	34.9	Reddish brown	2.0
02	35.0	Reddish brown	2.2
1	33.8	Reddish brown	2.5
3	33.5	Reddish brown	2.4
5	34.3	Brown and black	2.2
7	32.7	Brown and black	2.2
9	34.0	Black	1.9

The burned pieces are weak.

Fusion test:—No. 45 deforms at cone 30.
No. 1678 deforms at cone 28.

Summary

This clay has a medium high strength tested alone and a medium bonding strength. This is particularly interesting because the screen test shows the presence of a high content of fine grained sand which does not impair its working properties. The drying shrinkage is medium. It shows a very open burning body at all temperatures with low burning shrinkages. The fusion test indicates a refractory clay.

Such open burning refractory clays having good plasticity and strength are of value used alone or in mixtures in the manufacture of refractory wares.

Sample No. 44 [resampled as No. 1691]

(2 miles east of Grand Chain)

This is a soft clay of a gray color. It develops a fair degree of plasticity.

Water of plasticity .... *per cent* 33.8
Shrinkage water .... *per cent* 21.4
Pore water .... *per cent* 12.4
Modulus of rupture .... *lbs. per sq. in.* 465.6
With 50% standard sand—Modulus of rupture .... *lbs. per sq. in.* 325.6
Slaking test .... *min.* 32

Screen test:—

Mesh	Residue Per cent	Character of Residue
20	Trace	....
40	Trace	Mica
60	Trace	....

80	Trace	....
120	1.32	Mica and sand
150	5.47	Mica and sand
200	4.80	Mica and sand

Drying shrinkage:—

	Per cent
Linear; wet length	6.8
Linear; dry length	7.0

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*
08	31.0	Light gray	1.45
06	27.6	Light gray	2.24
04	23.2	Cream	3.81
02	22.2	Cream	3.6
1	17.2	Cream	4.1
3	17.4	Cream	4.6
5	11.5	Grayish	4.9
7	12.3	Grayish	5.1
9	10.4	Grayish	5.3
11	10.9	Grayish	5.0

Fusion test:—It deforms at cone 29.

Summary

This clay has a medium high bonding strength. The drying shrinkage is medium. It does not reach a low porosity within the temperature range employed—up to cone 11. The shrinkage at cone 9 is medium. It is a refractory clay, but not of high grade. In addition to its use in refractories, it is of the type used for stoneware, architectural terra cotta, and sanitary ware.

Sample No. 17

(River bank at Caledonia)

This is a clay of rather hard and shaly character which seems to contain a considerable quantity of mica. The clay is of a brownish color marked with yellow specks. It has rather a poor degree of plasticity and does not flow satisfactorily through a die.

Water of plasticity	*per cent*	80.9
Shrinkage water	*per cent*	28.1
Pore water	*per cent*	52.8
Modulus of rupture	*lbs. per sq. in.*	180.9
Slaking test, average	*min.*	4

Screen test:—

Mesh	Residue *Per cent*	Character of residue
10	0.25	Particles of clay
14	2.2	Particles of clay
20	8.8	Particles of clay
35	19 5	Sand and clay
48	6.3	Clay and flakes of mica
65	4.3	Clay and flakes of mica
100	5.0	Clay and flakes of mica
150	4.0	Clay and flakes of mica
200	4.1	Clay and flakes of mica

Drying shrinkage, linear .... *per cent* 5.0
Volume .... *per cent* 25

Burning test:—

Cone	Porosity *Per cent*	Color	Remarks
02	38.6	Light brown	Poorly oxidized
1	38.2	Light brown	....
3	38.8	Light brown	....
5	38.6	Darker brown	....
7	34.6	Darker brown	....
9	34.0	Black	Appears to show vitrification
13	14.8	Black	Overburned

Fusion test:—It melts to a glass below cone 26.

Summary

The strength of the clay is medium low. The percentage of screen residue is high. Its drying shrinkage is medium low. It appears to be overburned at cone 13 even though its porosity is still quite high.

The exceptionally high contents of water of plasticity and pore water indicates a very high colloidal content. Because of this the clay gives erratic results in the strength tests. This deposit has proved to be a good grade of fuller's earth and a plant is in operation preparing it for the market.

Sample No. 37a

(Barber farm; sec. 13, T. 15 S., R. 1 E.)

This is a light gray soft clay which contains many mica particles. The plastic mass is readily molded into shape and it flows well through a die.

Water of plasticity .... *per cent* 27.9
Shrinkage water .... *per cent* 14.9
Pore water .... *per cent* 13.0
Modulus of rupture .... *lbs. per sq. in.* 240.7
With 50% standard sand—Modulus of rupture .... *lbs. per sq. in.* 238.7
Slaking test, average .... *min.* 15

Drying shrinkage:—

	Per cent
Linear; wet length	3.2
Linear; dry length	3.4

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*
2	28.80	Cream	2.6
5	27.00	Cream	2.2
9	3.7	Light gray	6.1
12	7.2	Light gray	5.0
13½	13.0	....	2.4

Fusion test:—Complete fusion at cone 25.

Summary

This clay has medium strength. Its drying shrinkage is medium low. It develops a high degree of vitrification between cones 5 and 9 with a medium burning shrinkage. It overburns at cone 12 and is non-refractory since it fuses at cone 25.

The clay ought to find use for manufactures of stoneware, architectural terra cotta, sanitary ware and similar wares.

ALEXANDER COUNTY

CLAYS FROM THE AETNA POWDER COMPANY'S LAND

Bedded clays are exposed at several places on the land of the Aetna Powder Company. High on the ridge at the first separator house, at least 9 feet of gray laminated clay has been exposed in the excavation for the foundation. The clay is light drab to gray in color and interstratified with distinct beds of mica and fine sand. The section is as follows:

Section at first separator house of Aetna Powder Company at Fayville

	Thickness *Feet*
3. Loess, with soil at top	20
2. Gravel	1 to 2
1. Clay laminated (Sample No. 41); small crystals of gypsum	9

The clay could not be worked while this part of the plant is in operation. Results of tests of sample No. 41, which was taken from the upper 5 feet, are given below.

In the hollow behind the old powder plant, clay is exposed at several places. The section varies from place to place, but the following is representative:

Section behind old powder plant at Fayville

	Thickness *Ft.*	*In.*
7. Soil	1	3
6. Loess	10+	..
5. Clay and sand, ash colored	4	..
4. Sand, buff, but loosely cemented	5	6
3. Conglomerate layers, cemented by iron; pebbles up to 3 inches	1	6
2. Clay, lignitic	3	..
1. Clay, sandy, micaceous; very pure in places (Sample No. 42)	4	..

Most of this clay has 20 feet or more of overburden. Results of the tests on Sample No. 42 are given below.

RESULTS OF TESTS

ALEXANDER COUNTY

Sample No. 41

(Aetna Powder Company, at Fayville)

This is a micaceous clay of a gray color streaked with brown. It is moderately hard. When plastic, it is rather sticky.

Water of plasticity	*per cent*	32.3
Shrinkage water	*per cent*	21.9

Pore water	*per cent*	10.4
Slaking test, average	*min.*	8
Drying shrinkage, linear	*per cent*	8.6

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Total shrinkage *Per cent*	Remarks
02	18.9	Cream	3.9	12.5	Shrinkage determined on very small piece
13	8.4	Gray	3.9	12.5	Vitreous; conchoidal fracture; not overburned; shrinkage determined on very small piece

Fusion test:—⅓ deformed at cone 25. The cone appears to have developed a decided vesicular structure.

Summary

A very plastic and rather sticky clay, which has a medium drying shrinkage. It has a medium porosity at cone 02 and is still quite porous at cone 13 with a medium high shrinkage. Its fusion point is about cone 25, which places it amongst the non-refractory clays.

The incomplete tests indicate a clay which may be suited for stoneware, sanitary ware, or similar wares.

Sample No. 42

(Aetna Powder Company at Fayville)

The clay is a uniform light gray in color. It is rather hard. When tempered with water it has a fair degree of plasticity and flows through a die satisfactorily.

Water of plasticity	*per cent*	29.1
Shrinkage water	*per cent*	15.4
Pore water	*per cent*	13.6
Modulus of rupture	*lbs. per sq. in.*	283.1
Slaking test, average	*min.*	10
Drying shrinkage, linear		7.5

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
02	12.8	Cream	13.7	Hackly fracture, vitreous
5	1.3	Gray	16.0	......
9	0.0	Gray	17.5	......
13	0.0	......	17.5	......

Fusion test:—Cone down at cone 25. No vesicular structure seems to have been developed in the cone.

Summary

The clay has a medium strength. Its linear shrinkage is medium. The total shrinkage at cone 9 is high. Practically complete vitrification is reached at cone 5 and there are no signs of overburning at cone 13. It is a non-refractory clay.

Suggested uses: Stoneware, architectural terra cotta, sanitary ware, and face-brick.

CLAYS OF PENNSYLVANIAN AGE

Field and Laboratory Notes on Pennsylvanian Clays

Field notes by C. R. Schroyer
Tests by C. W. Parmelee

MONROE COUNTY

Clay outcrops in St. Clair County along a small creek that flows southwest in the SW. ¼ sec. 22, T. 1 S., R. 10 W. The clay is at the base of the Pennsylvanian system, specifically at the Cheltenham horizon. At the outcrop it is mottled yellow and white, plastic, and comparatively free from sand. Borings show that the yellow color is restricted to the upper part where there is an overburden of gravel and glacial drift.

Section of clay 1 mile south of Columbia

	Thickness *Ft.*	*In.*
5. Overburden, clay and gravel	0 to 20	..
4. Clay, yellow and white (by boring)	10	8
3. Clay, white, exposed in bank of creek	2	..
2. Clay; boring in bed of creek (Sample No. 61)	3	6
1. Limestone, Mississippian	..	..

The slope above the creek has slumped and it is uncertain if this thickness of 16 feet 2 inches represents the maximum thickness of the clay, which is exposed for 320 feet along the stream. A well 28 feet in depth ended in loose sand less than a quarter of a mile east of the outcrop. Other wells which should have reached the clay if it were a persistent bed, have not revealed it elsewhere.

The quantity of this clay, though apparently small, is probably sufficient so that development for use as a blend with other clays might be considered. It is at the horizon of the Cheltenham clay of the St. Louis district. Sample No. 62 was taken from a boring which penetrated the entire thickness.

RESULTS OF TESTS

MONROE COUNTY

Sample No. 61

(1 mile south of Columbia)

This is a medium hard, grayish-colored clay, mottled with dark brown. It has a medium hardness. When tempered with water it becomes very plastic.

Water of plasticity	*per cent*	33.5
Shrinkage water	*per cent*	20.5
Pore water	*per cent*	13
Modulus of rupture, average	*lbs. per sq. in.*	567
minimum	*lbs. per sq. in.*	420
maximum	*lbs. per sq. in.*	773
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	372.7
Slaking test, average	*min.*	16
Drying shrinkage, linear	*per cent*	8.4

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	Trace	....
35	Trace	....
60	0.32	Colored sand
120	0.3	Colored sand
200	Trace	Colored sand

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	1.5	Tan	7.6	Hackly, vitreous
2	0.6	Tan	7.4	Hackly, vitreous
5	1.6	Tan	6.9	Vitrified, hackly
9	6.1	Tan	6.3	Overburned
13	7.0	Dark tan	5.3	Overburned

Fusion test:—Complete fusion before cone 26.

Summary

This clay has an exceptionally good strength when tested alone, but only medium when mixed with standard sand. It is very free from all particles coarser than 200 mesh. The drying shrinkage is medium. It develops a high degree of vitrification at an exceptionally low temperature and overburns at cone 5. It is completely fused before cone 26 is reached and therefore is a non-refractory clay.

This clay will probably be most useful for the manufacture of brick and blocks, etc., for building purposes, and possibly pavers.

Sample No. 62
(1 mile south of Columbia)

The sample borings are a gray color, mottled with yellow. When mixed with a suitable quantity of water, the clay becomes very plastic.

Water of plasticity	*per cent*	38.9
Shrinkage water	*per cent*	22.9
Pore water	*per cent*	15.9
Slaking test, average	*min.*	8
Drying shrinkage, linear	*per cent*	8.5

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Burning shrinkage *Per cent*	Remarks
02	1.5	Terra cotta	3.7	11.2	Vitrified
1	1.8	Light brown	4.0	12.5	Vitrified
5	0.7	Reddish brown	....	....	Vitrified conchoidal fracture
9	5.0	Reddish brown	....	6.5	Overburned
13	8.5	Reddish brown	....	....	Vesicular

Fusion test:—Completely fused at cone 27, vesicular.

Summary

This is a non-refractory clay which vitrifies at a very low temperature and overburns between cones 5 and 9. Its drying shrinkage is medium. Burning shrinkage at cone 1 is high.

It is suited for use in the manufacture of building brick and common wares.

MADISON COUNTY

"The outcrop of the fire clay in Madison County extends from a point on the county line north of Godfrey southerly and easterly to East Alton. South of East Alton it is cut off by the alluvium of the Mississippi River bottom. Fire clay is found, however, two miles east of Collinsville at Cantine at a depth of 270 feet, and it seems probable in view of the extent of the fire clay into the St. Louis district, that it may be found underlying the entire county."[1]

This clay is used for sewer pipe by the East Alton Stoneware Pipe Company at their plant 1½ miles northeast of East Alton.

Section of the Stoneware Pipe Company's shaft at East Alton in the NE. ¼ sec. 15, T. 5 N., R. 9 W.

		Thickness Ft.	In.
7.	Shale, light colored; flint concretion and nodules of carcarous ironstone	50	..
6.	Shale, black; "slate" of miners	1	6
5.	Coal (No. 2)	2	3
4.	Clay, "little vein"	4	..
3.	Limestone; hard, flinty, brecciated beds	7	..
2.	Fireclay: Green shale—3 in.; Dark shale—2 in.; Coal—1 in.; Light colored fireclay—3 ft. (Sample No. 59); Dark clay, colored by carbon—11 ft. (Sample No. 60)	14	6
1.	Sandstone, brown, below	..	..

Only the uppper 2½ to 3 feet of the dark clay and the 3 feet of light clay are used for sewer pipes. The lower beds run high in sulphur and contain large amounts of pyrite. These lower beds are variable in thickness and in places missing, so that the total thickness is not over six feet. At the old mines in the NW. ¼ sec. 15 the thickness is reported to have been about seven feet.

RESULTS OF TESTS

MADISON COUNTY

Sample No. 59

(Stoneware Pipe Company's shaft; NE. ¼ sec. 15, T. 5 N., R. 9 W.

A very hard, dark gray colored clay which develops a good plasticity although a little sticky. It flows satisfactorily through a die when rather soft.

Water of plasticity	*per cent*	36.2
Shrinkage water	*per cent*	24.0

[1]Lines, Edwin H., The Pennsylvania fire clays of Illinois: Ill. State Geol. Survey Bull. 30, p. 66, 1917.

Pore water	*per cent*	12.2
Modulus of rupture	*lbs. per sq. in.*	589.0
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	169.8
Slaking test	*hours*	6

Screen test:—

Mesh	Residue *Per Cent*	Character of residue
40	.17	Pyrites
60	4.57	Pyrites, hard particles of clay and fine sand
80	1.05	Pyrites, fine sand, and clay
120	6.76	Pyrites, sand, and clay
150	1.4	Pyrites, mica, fine sand, mostly clay
200	1.44	Mica, fine sand and clay

Drying shrinkage:—

	Per cent
Linear; wet length	9.72
Linear; dry length	10.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	3.4	Grayish white	6.3	
5	2.4		6.6	Black core
9	5.4	Tan exterior	5.7	Black core
12	14.2	Red tan exterior, bluestoned interior	3.4	
13	11.9		2.3	
15	10.0	Buff bluestoned	2.9	Large iron slag spots

Oxidation conduct:—Very difficult to oxidize.
Fusion test:—Down at cone 28.

Summary

A clay which has medium high strength when tested without admixture of sand but shows a medium low bonding power. It contains a notable amount of mineral particles which are retained upon the screens. The presence of pyrite amongst these explains the slag spots formed at high temperatures as well as the pitted and vesicular appearance of the fusion test. Undoubtedly this clay can be greatly improved by washing. The drying shrinkage is medium high and the burning shrinkage at cone 9 is medium high. Its low porosity at cone 2 is unusual. The overburning which develops between cones 9 and 12 is undoubtedly due to the high carbon and sulphur content. It is a difficult clay to oxidize.

It is thought that the purification of this clay by washing will greatly improve its properties and extend its usefulness; otherwise, it will be very difficult to use because of its high carbon-sulphur content and consequent slow oxidation.

Sample No. 60

(Stoneware Pipe Company's shaft; N.E. ¼ sec. 15, T. 5 N., R. 9 W.)

The sample is a dark brown clay, having a flinty hardness. Its plasticity is good although it is slightly sticky. When it has rather a soft consistency, it flows well through a die.

Water of plasticity	*per cent*	33.05
Shrinkage water	*per cent*	23.05
Pore water	*per cent*	10.0
Modulus of rupture	*lbs. per sq. in.*	427
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	164.5
Slaking test	*hours*	5

Screen test:—

Mesh	Residue *Per cent*	Character of residue
60	Trace	Particles of sand
80	Trace	....
100	0.16	Fine sand
150	0.17	Fine sand and organic matter
200	0.15	Fine sand and organic matter

Drying shrinkage:—

	Per cent
Linear; wet length	8.72
Linear; dry length	9.3

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Total shrinkage *Per cent*	Remarks
2	2.45	Red	7.28	15.5	Vitreous
5	1.5	Grayish	7.3	....	Black core
9	0.7	Gray exterior	7.4	....	Black core
12	2.6	Tan exterior; bluestoned	7.8	....	....
13	3.8	....	6.1	....	Overburned

Fusion test:—Cone 31—bloated.

Summary

This clay is similar in some respects to sample No. 59. Its bonding strength is medium low although the pure clay has a considerably higher modulus of rupture. It contains very little material too coarse to pass a 200-mesh sieve. The drying shrinkage is medium high. The burning conduct is of particular interest because of the low porosity reached at a low cone (2) and maintained over a wide range of temperature. There are some slight indications of overburning above cone 12. The presence of a black core at cones 5 and 9 indicates that care will be required in oxidizing this clay during burning.

Suggested uses: Its property of burning dense at a low temperature and maintaining a wide vitrification range ought to make it desirable for vitrified or close bodies. It may possibly serve for pavers although the poor oxidation conduct may prevent this. It is being used for sewer pipe and probably would serve for conduits. The color of the burned clay is not satisfactory for stoneware. It may possibly be used for architectural terra cotta.

CALHOUN COUNTY

Formerly a plant at Golden Eagle manufactured fire brick from the clay lying directly below the No. 2 coal. The mines are in bad condition (fig. 53) and no measurement of the clay could be made. Five feet of the upper part of the seam was mined. At the bottom of this level are nodular limestone boulders full of pyrite crystals. Smaller boulders were found scattered through the clay. The sample No. 58 was taken from a pile of clay which had been dug several years previous. However this clay was still unslacked and appeared fresh and in good condition.

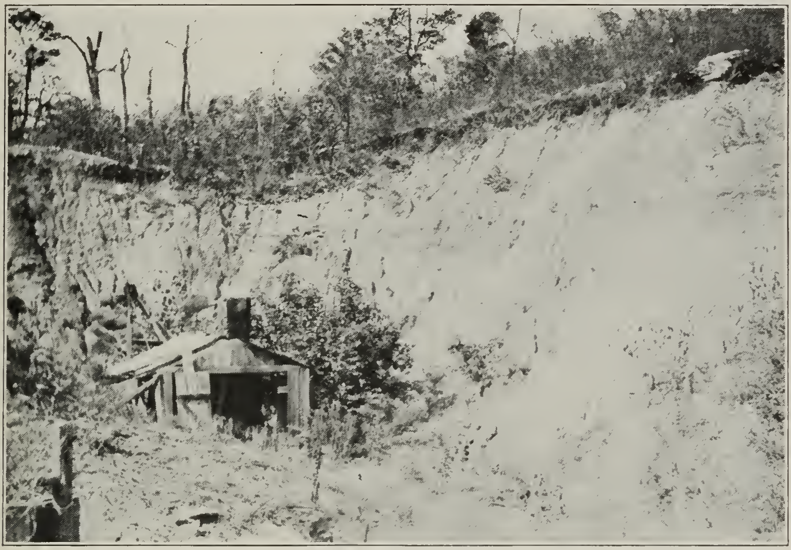


FIG. 53. Abandoned fire clay pit at Golden Eagle.

The area underlain by this clay is small, but with the present equipment might again justify operation. Directly above the clay is a two-foot coal bed which is mined with it. Transportation is entirely by water.

RESULTS OF TESTS

CALHOUN COUNTY

Sample No. 58

(Abandoned plant at Golden Eagle)

This is a very hard grayish colored clay which contains much finely divided pyrite. Upon the addition of a suitable amount of water it develops a good but sticky degree of plasticity. It slakes very slowly.

Water of plasticity	*per cent*	34.4
Shrinkage water	*per cent*	25.5
Pore water	*per cent*	18.9
Modulus of rupture	*lbs. per sq. in.*	165.7
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	124.6
Slaking test	*hours*	5½

Screen test:—

Mesh	Residue *Per cent*	Character of residue
120	.50	Pyrites, fine sand and particles of sand
150	.09	Mica and sand
200	.12	Pyrites, sand, clay and organic material

Drying shrinkage:—

	Per cent
Linear; wet length	10.05
Linear; dry length	11.6

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	10.0	....	6.1	....
5	5.2	Tan	6.0	Small black core
9	7.0	Buff	4.3	Black core, fine iron spots
12	5.0	Buff exterior; bluestoned	5.0	
13	7.0	....	2.6	Flashed
15	5.5	Buff; bluestoned	2.8	Overburned

Fusion test:—Cone ⅓ deformed at cone 26. The cone has a vesicular structure.

Summary

This clay has a medium low strength and a medium low bonding strength. The drying shrinkage is medium high. The effect of the small residue of finely divided pyrite becomes evident at the higher temperatures, especially in the fusion test. Washing the clay for some products will correct this. The poor oxidation conduct should be noted. The clay is on the border line between a non-refractory and a refractory material. The test piece has the appearance of having been overfired at cone 15.

Suggested uses: Architectural terra cotta, face brick.

GREENE COUNTY

At White Hall, Greene County, fireclay has long been dug for use in the manufacture of sewer pipe, and stoneware and refractory clay has been shipped widely from the pits at Drake.

Two miles southeast of Hillview in the S. ½ sec. 34, T. 12 N., R. 13 W., a small amount of clay has been recovered from above the Mississippian limestone. This is probably a residual clay from the decay of the limestone and if so, does not properly belong in the Pennsylvanian system.

The clay has a greenish or bluish white color when wet, but whitens upon drying. The exposed part contains abundant cherty and calcareous nodules, and gritty calcareous sand. The thickness may locally be as much as 10 feet but the distribution is irregular and pockety, conforming as it does into the irregular surface of the underlying weathered limestone.

Section of the small opening in S. ½ sec. 34, T. 12 N., R. 13 W.

	Thickness *Feet*
4. Loess and soil	10 ±
3. Gravel	2
2. Clay, blue, containing calcareous sand and small gravel; traces of pink (Sample No. 57)	3
1. Limestone, residual, decomposed, and cherty; covered at base but underlain by bedded limestone further down the ravine	12

The extent of this clay is uncertain, but it has been found in nearby wells to the west. A few carloads have been dug from the slope above the limestone one mile west of this outcrop where a boring is said to have penetrated 9 feet of clay. The results of the tests made on sample No. 57 are given on pages 352 and 353.

The overburden would range from 15 to 35 feet, depending upon how far the working penetrated the divides.

Washing would be necessary to make this clay suitable for use as a refractory.

The results of the tests made on sample No. 55 which is from the E. N. Ford farm near Hillview, are given on pages 353 and 354.

Clay has not been shipped from Drake for over two years. Previous to that time it had been shipped more widely than any other in Illinois. The greatest thickness of clay ever dug was 26 feet. A well penetrated 8 feet of clay below this. As both the top and bottom are irregular, the thickness is variable and becomes as little as 5 feet. An eighth of a mile south of the station it is 20 feet thick.

The overburden varies from 10 to 40 feet, a thickness that makes the working of the old pit unprofitable.

The clay has an Indian red color locally, especially near the top of the west pit, which renders the clay useless for refractory purposes.

Clay is also reported from north of the railroad at Drake, where a well section was given as follows:

Log of well north of Drake

Description of strata	Thickness *Ft.*	Depth *Ft.*
"Earth"	12	12
Not described	8	20
Sandstone	7	27
Clay	15	42
Limestone	..	..

Sample No. 136, sent in by Mr. A. M. Cain, was taken from a shallow pit north of the railroad. Sample No. 54 was taken from the lower clay; sample No. 56 from the upper clay, ¼ mile south of Drake. Sample No. 53 from the farm of C. T. Hicks, ⅛ mile south of Drake. The results of tests on these samples are given on pages 354 to 358.

Section of clay pits east of White Hall

	Thickness Ft.	In.
6. Soil and yellow underlying hardpan	3	..
5. Clay, yellow, and till	16	..
4. Shale and clay, sandy; stringers of gravel	17	5
3. Clay, buff and white (Sample No. 49)	3	5
2. Clay, bluish with scattered purplish red and dark stains (Sample No. 52)	7	6
1. Partly covered to deepest part of pit; clay not now worked	3	6

The clay above as well as that below is used entirely for sewer pipe and stoneware by the White Hall Sewer Pipe and Stoneware Company at their plant in White Hall. Results of tests on samples No. 49 and No. 52 are given on pages 358 to 360.

Section 2½ miles northeast of White Hall

	Thickness Ft.	In.
6. Drift	12	..
5. Shale, local	1	10
4. Coal (No. 2)	2	6
3. Clay, yellow, sandy	4	..
2. Clay, white and buff (Sample No. 51)	6	..
1. Clay, bluish; iron concretions in places; used for sewer pipes (Sample No. 50)	17	6

The results of tests made on samples No. 51 and No. 50 are given on pages 360 to 362. Lines[1] says of this area: "It is reported * * * that good deposits extending another mile east are available when the present pits are worked out. The dip of the rocks here is easterly, and nothing is known of the clay after it gets below drainage, but it is possible that shafts would reach the clay over a large area."

RESULTS OF TESTS

GREENE COUNTY

Sample No. 57

(S. ½ sec. 34, T. 12 N., R. 13 W.)

The sample is a gray colored clay stained with yellow and containing a few black spots. When tempered with water it is very plastic.

Water of plasticity	*per cent*	25.9
Shrinkage water	*per cent*	14.9
Pore water	*per cent*	11.0
Modulus of rupture	*lbs. per sq. in.*	565.5
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	370
Slaking test, average	*min.*	9
Drying shrinkage, linear	*per cent*	7.0
Volume	*per cent*	27.6

[1]Lines, Edwin H., Pennsylvanian fire clays of Illinois: Ill. State Geol. Survey Bull. 30, p. 67, 1914.

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	12.9	Gray	12.5	
1	18.9	Cream	11.1	
3	1.5	Dark gray	12.5	Vitreous conchoidal fracture
5	0.3	Dark gray	13.1	
7	0.4	Dark gray	12.5	Glassy fracture
9	0.6	Dark gray	12.1	Glassy fracture
13	0.6	Dark gray	11.7	Glassy fracture

Small particles of some more fusible mineral are scattered through the mass.

Note:—Grayish color of cone 3 et seq. may be due to reduction.

Fusion Test:—Fused completely at cone 26.

Summary

The strength of the unburned clay is medium high and the bonding strength is medium. The drying shrinkage is medium and at cone 9, the total shrinkage is medium. The test pieces were virtually non-porous at cone 3 and showed no signs of overburning at cone 13, indicating a very long range of vitrification. It is not a refractory clay.

Suggested uses: The very satisfactory strength tests together with the early vitrification and long heat range suggest a clay useful for stoneware, architectural terra cotta, sewer pipe, and paving brick. The rapid rate of vitrification between cones 1 and 3 may prove to limit its usefulness.

Sample No. 55

(E. N. Ford farm, near Hillview)

This clay is colored brown mottled with gray. It contains numerous lumps of limestone varying in size from a small grain to a hazel nut. The clay tempered with water has good plasticity but is slightly sticky if too wet. Its conduct when squeezed through a die is fair.

Water of plasticity	*per cent*	39.5
Shrinkage water	*per cent*	25.4
Pore water	*per cent*	14.1
Modulus of rupture	*lbs. per sq. in.*	172.5
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	145.17
Slaking test, average	*min.*	55

Screen test:—

Mesh	Residue *Per cent*	Character of residue
40	.25	Light colored particles, few sand grains
60	.97	Light colored particles, few sand grains
80	.23	More fine sand
120	.42	Light particles and fine sand
150	.18	Light and colored
200	.07	Fine sand, mica, light and hard particles

Drying shrinkage:—

	Per cent
Linear; wet length	6.05
Linear; dry length	7.52
Volume	25.0

Burning test:—

Cone	Porosity	Color	Burning shrinkage	Remarks
	Per cent		*Per cent*	
2	2.19	Very light tan	9.58	
5	0.5	Very light tan	9.58	
9	3.3	Gray	9.78	Vitreous fracture
12	4.62	Gray with iron spots	8.4	Small light red iron spots slagged in the piece
13	9.0		6.3	

Fusion test:—Deforms at cone 29.

Summary

This is a clay of a medium low strength and medium low bonding strength. It has only a slight amount of screen residues coarser than a 200 mesh. The drying shrinkage is medium. It is practically non-absorbent at cone 2 and overburns between cones 5 and 9. The shrinkage at cone 9 is high. Although the test cone did not deform until cone 29 was reached, yet there were numerous slag spots indicating advanced stages of fusion in local areas.

Suggested uses: Face brick, sewer pipe (?), paving brick (?), architectural terra cotta, sanitary ware.

Sample No. 136

(A. M. Cain; near Drake)

This sample is a sandy, hard clay of a light gray color, mottled with brown. It has a medium plasticity and is inclined to be sticky. When forced through a die it flows satisfactorily.

Water of plasticity	*per cent*	25.6
Shrinkage water	*per cent*	14.9
Pore water	*per cent*	10.7
Modulus of rupture	*lbs. per sq. in.*	586
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	376
Slaking test, average	*min.*	28

Screen test:—

Mesh	Residue	Character of residue
	Per cent	
20	5.31	Quartz particles
40	.39	Quartz particles
60	1.67	Quartz particles
80	.55	Quartz particles, white and brown
120	3.76	Quartz particles
200	2.96	Quartz particles, mostly brown

Drying shrinkage:—

	Per cent
Linear; dry length	9.5
Linear; wet length	10.7
Volume	28.8

Burning test:—

Cone	Porosity	Color	Burning shrinkage
	Per cent		Per cent
04	24.7	Salmon	+0.65
02	25	Red brown	+0.8
2	23.7	Red brown	0.2
5	23	Red brown	1.4
9	20	Chocolate	1.5
13	21	Chocolate	3.1

Fusion test:—Completely deformed at cone 25.

Summary

This clay has a medium high strength, tested alone, but its bonding strength is medium. It contains a considerable amount of quartz sand. The drying shrinkage is medium high. The total shrinkage at cone 9 is medium. The burning shrinkages at all temperatures are low. In fact, there is a slight swelling at temperatures up to cone 1. The clay is open burning since its porosities are high at cones 5 and above. It is non-refractory.

It is suited best for brick and similar products having a dark color and high porosity.

Sample No. 54

(¼ mile south of Drake)

This is a soft clay of a light gray color mottled strongly with darker gray and occasional brown spots. After the addition of a suitable amount of water it develops good plastic properties and flows fairly well through a die.

Water of plasticity	*per cent* 24.5
Shrinkage water	*per cent* 11.7
Pore water	*per cent* 12.8
Modulus of rupture	*lbs. per sq. in.* 250
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.* 220

Screen test:—

Mesh	Residue	Character of residue
	Per cent	
20	0.13	Roots and rock particles
40	0.03	Roots and rock particles
60	0.15	Quartz sand
80	0.03	Quartz sand
120	0.54	Quartz sand, and mica
200	4.2	Quartz sand, and mica

Drying shrinkage:—

	Per cent
Linear; dry length	5.7
Linear; wet length	5.4
Volume	24.1

Burning test:—

Cone	Porosity Per cent	Color	Burning shrinkage Per cent	Remarks
02	22	White	..	
1	22	White	..	
3	21	Light cream	2.8	Earthy fracture, vanadium? stain
5	20	Light cream	3.5	
6	19	Light cream	3.9	Earthy fracture, vanadium? stain, slight iron stain
8	16	Dark cream	4.1	Earthy fracture, vanadium? stain, slight iron stain
12	7.6	Cream, bluestoned slightly	5.7	
13	4.0	Light tan exterior, bluestoned	5.8	
15	4.0	Tan exterior, bluestoned	6.9	

Fusion test:—Deforms at cone 29.

Summary

This is a clay having medium bonding strength. The drying shrinkage is medium. It contains very little material coarser than a 200 mesh. The burning shrinkage at cone 8 is medium. Samples burned up to and including cone 8 have quite a high porosity. This decreases rapidly between cones 8 and 12. It is a refractory clay.

Possible uses: Architectural terra cotta, sanitary ware, stoneware, face brick, as a bond clay in refractories.

Sample No. 56

(¼ mile south of Drake)

A medium soft clay colored light gray, with brown stains and containing a few black nodules. When tempered with water it is very plastic and flows well through a die.

Water of plasticity	*per cent*	21.2
Shrinkage water	*per cent*	10.1
Pore water	*per cent*	11.1
Modulus of rupture	*lbs. per sq. in.*	462
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	231.8
Slaking test, average	*min.*	14

Screen test:—

Mesh	Residue Per cent	Character of residue
20	0.3	Rootlets and rock particles
40	0.12	Rootlets and quartz grains

60	0.33	Rootlets and white quartz grains
80	0.08	....
120	3.42	White sand and mica with some organic matter
200	8.59	White sand

Drying shrinkage:—

	Per cent
Linear; dry length	4.9
Linear; wet length	4.7
Volume	19.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
1	23	Cream	2.2	....
2	20	Cream	2.5	Earthy fracture
3	21.4	Light cream	3.4	Earthy fracture
6	19	Light cream	3.3	Earthy fracture, slight veining of iron stain
9	15	Cream	3.5	Earthy fracture
12	7	Dark cream	4.4	Earthy fracture
13	4	Light tan exterior; bluestoned	4.5	Very minute glassy spots on and in the piece
15	5	Light tan; bluestoned	..	....

Fusion test;—Cone 28.

Summary

The strength of the dry clay is medium high. Its bonding strength is medium. The amount of residues on the screens is small. The drying shrinkage is medium low and the total shrinkage at cone 9 is medium. It is a refractory clay.

Suggested uses: Architectural terra cotta, stoneware, sanitary ware, face brick, refractory wares.

Sample No. 53

(C. T. Hicks; ⅛ mile south of Drake)

This is a hard clay of a light gray color mottled with brown and darker gray color. When tempered with water it develops a good degree of plasticity and may be made to flow satisfactorily through a die.

Water of plasticity	*per cent*	17.2
Shrinkage water	*per cent*	8.74
Pore water	*per cent*	8.51
Modulus of rupture	*lbs. per sq. in.*	120.2
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	103.1

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	0.3	Quartz grains, rock grains and roots

40	.09	Quartz grains, rock grains and roots
60	1.0	White sand with darker particles
80	0.4	White sand with darker particles
120	3.8	White sand with darker particles
200	4.6	White sand with darker particles

Drying shrinkage:—

	Per cent
Linear; dry length	4.0
Linear; wet length	3.8
Volume	17.1

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	26	White	2.4	Earthy fracture
3	23	Very light cream	3.6	Earthy fracture shows vanadium (?) stain
6	22	Very light cream	4.4	Earthly fracture. Iron spots, very small
8	19	Very light cream	4.6	....
9	18.2	Very light cream	4.9	....
12	13.0	Very light cream	6.2	....
13	7.6	Very light cream	6.2	Iron spots, very small and not conspicuous
15	7.0	Bluestoned; tan exterior	7.5	....

Fusion test:—Deforms at cone 30.

Summary

This clay has a medium low strength and a medium low bonding strength. The amount of the residues left upon the screens is moderate. The drying shrinkage is low. Shrinkage at cone 8 is medium. Vitrification proceeds slowly until cone 13 is reached. It is a refractory clay.

Suggested uses: Face brick, architectural terra cotta, sanitary ware, and refractories.

Sample No. 49

(Clay pit east of White Hall)

This is a light gray colored clay with brown stains which is moderately hard. Good plasticity is developed upon the addition of water, and in this condition it flows readily through a die.

Water of plasticity	*per cent*	24.3
Shrinkage water	*per cent*	11.2
Pore water	*per cent*	13.1
Modulus of rupture	*lbs. per sq. in.*	369.2
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	189.5
Slaking test, average	*min.*	23

Screen test:—

Mesh	Residue Per cent	Character of residue
20	0.46	Colored sand
40	0.37	Colored sand
60	1.94	Colored sand
80	0.54	Colored sand
120	0.13	Colored sand
200	Trace	Colored sand

Drying shrinkage:—

	Per cent
Linear; wet length	4.75
Linear; dry length	4.98
Volume	21.2

Burning test:—

Cone	Porosity Per cent	Color	Burning shrinkage Per cent	Remarks
2	22.8	Cream	7.2	....
3	18.4	Light cream	7.2	Smooth fracture; very fine iron speck
6	16.5	Cream	7.2	Smooth fracture; very fine iron speck
8	12.9	Cream	5.8	....
9	9.6	Cream	5.6	Smooth fracture, very fine iron speck
12	0.5	Gray interior; light tan exterior	7.0	....
13	1.01	....	6.5	....
15	8.8	Bluestoned; buff exterior	6.0	Very small iron spots

Fusion test:—It fused at cone 30.

Summary

The clay has a medium strength and medium low bonding strength. The amount of screen residues is slight. The drying shrinkage is medium low and the burning shrinkage at cone 9 is medium. The clay vitrifies to a porosity of less than one percent between cones 9 and 12. Overburning appears at about cone 15.

Suggested uses: Stoneware, architectural terra cotta, face brick, sanitary ware, refractories.

Sample No. 52

(Clay pit east of White Hall)

This is a hard dark gray colored clay mottled with yellowish brown. When ground and tempered with water it develops a good plasticity and flows readily through a die.

Water of plasticity	*per cent*	23.0
Shrinkage water	*per cent*	9.9
Pore water	*per cent*	13.1
Modulus of rupture	*lbs. per sq. in.*	380.2
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	243.9
Slaking test, average	*min.*	10

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	Trace	....
35	0.12	Particles of shale, coal and sand
48	0.10	Particles of shale, coal and sand
65	0.15	Particles of shale, coal and sand
100	2.0	Particles of shale, coal and sand with much mica
150	3.8	Particles of shale, coal and sand with much mica
200	8.1	Particles of shale, coal and sand with much mica

Drying shrinkage:—

	Per cent
Linear; dry length	5.0
Volume	18.5

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
02	21.6	Light tan	9.1	....
1	15.7	Light tan	10.4	....
3	10.6	Tan	10.1	....
5	7.2	Gray[1]	10.4	Semi vitreous fracture
8	2.5	Gray[1]	11.3	Vitreous luster
13	1.6	Gray	11.0	Vitreous luster, conchoidal fracture

Fusion test:—Fused completely at cone 26.

Summary

The clay has a medium strength and a medium bonding strength. The screen residues are considerable. The drying shrinkage is medium low. The total shrinkage at cone 8 is medium. The clay is well vitrified at cone 8 and is not overburned at cone 13. It is non-refractory.

Suggested uses: Stoneware, sanitary ware, architectural terra cotta, face brick.

Sample No. 51

(2½ miles northeast of White Hall)

This is a rather hard clay of a dark brown color and good plasticity. Its conduct when squeezed through a die is fair.

Water of plasticity .... *per cent* 24.0
Shrinkage water .... *per cent* 14.1

[1]Grayish color may be due to reduction.

Pore water	*per cent*	9.9
Modulus of rupture	*lbs. per sq. in.*	446.8
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	199
Slaking test, average	*min.*	11

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	Trace	....
60	Trace	....
80	Trace	....
120	0.18	Colored sand
200	1.4	White sand and mica

Drying shrinkage:—

	Per cent
Linear; dry length	6.4
Linear; wet length	6.0
Volume	27.8

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	19.	White	4.8	....
3	16.2	Light cream	5.3	Smooth, fine grain fracture
6	13.5	Light cream	5.3	Smooth fracture, nearly vitreous
8½	9.8	Cream	5.8	Smooth fracture, nearly vitreous
9	9.5	Cream	6.1	Smooth fracture, nearly vitreous
12	1.1	Stoneware gray, uniform	7.6	Smooth fracture
13	0.5	Stoneware gray, uniform	7.6	Smooth fracture

Soluble salts:—Pieces burned at cone 02 give a strong yellow surface discoloration after being soaked in water.

Fusion test:—Deforms at cone 31.

Summary

The strength of the raw clay is medium high. The bonding strength is medium low. The percentage of screen residues is slight. The drying shrinkage is medium. The total shrinkage at cone 9 is medium. Clay is well vitrified at cone 12. It is a refractory clay.

Suggested uses: Refractories, stoneware, architectural terra cotta, sanitary ware, face brick.

Sample No. 50

(2½ miles northeast of White Hall)

This clay is of a dark gray color with some portions brown and other reddish. It is quite hard but a good plasticity is developed when it is mixed with water and properly worked. Its conduct when flowing through a die is fair.

Water of plasticity	*per cent*	22.4
Shrinkage water	*per cent*	10.6
Pore water	*per cent*	11.8

Modulus of rupture	*lbs. per sq. in.*	207
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	275.5
Slaking test, average	*min.*	11

Screen test:—

Mesh	Residue *Per cent*	Character of residue
40	Trace	Quartz particles
60	0.38	Quartz particles
80	Trace	....
120	1.57	Mica and quartz sand
200	4.7	Mica and quartz sand

Drying shrinkage:—

	Per cent
Linear; dry length	5.9
Volume	21.8

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
04	28.6	Light tan, pinkish	0.13	....
02	25.1	Cream, pinkish	1.5	....
2	20.6	Light tan	3.1	Very fine iron spots
5	20.1	Tan	3.3	....
9	13.1	Stoneware gray	4.6	Smooth fracture
13	10.8	Stoneware gray	4.5	....

Fusion test:—It fused completely at cone 26.

Summary

The strength of the dry clay is medium. The bonding strength is medium. The quantity of screen residue is small. The shrinkage at cone 9 is medium. It is a non-refractory clay.

Suggested uses: It is reported as being used for sewer pipe. It appears adapted for stoneware, architectural terra cotta, sanitary ware, and face brick.

SCOTT COUNTY

The clay at Alsey underlies 5 feet of cherty limestone, above which there are 28 to 34 inches of coal. Between these is a 2- to 3-foot thickness of dark, shaly clay. Only the upper part of the lower clay is dug, as the lower beds contain much pyrite. Almost the entire output of the plant had come to be fire brick when it closed in February, 1918, though formerly only building brick was made.

Production ran about 20,000 bricks per day but enlargement of the plant insures a possibility of double that quantity.

The United States Bureau of Standards reports above the signature of A. V. Bleininger, "In the fusion test, conducted in an electric furnace, the softening point of the fire brick was found to correspond to cone 31½, or approximately 3083 degrees F. From this it appears that the fire clay may be considered of No. 1 grade."

Sample No. 71 was taken from the stock pile of the clay used for fire brick and No. 70 from the clay which overlies the limestone. Results of tests are given on pages 364 and 365.

The Cheltenham clay is exposed in the bluff of Mauvais Terre Creek half a mile west of Exeter. The section varies in short distances, and the clay is stained yellow by iron along seams where water circulates. Gypsum crystals may be seen on the weathered surface. This clay was used several years ago by potteries at Exeter and Merritt.

Section along Mauvais Terre Creek half a mile west of Exeter

	Thickness Ft.	In.
8. Limestone; weathers to rounded boulders, some of large size. Hard; fossiliferous	3	10
7. Clay, yellow and impure	2	10
6. Clay, dark blue	3	10
5. Clay, drab yellow irony seams, gypsum crystals; the lower 4 feet sandy and not included in sample; probably high in sulphur and iron	12	6
4. Clay, somewhat colored by carbon	..	8
3. Coal and coaly shale	1	0 to 6
2. Conglomerate, sandy; pebbles up to the size of a walnut	2	0 to 6
1. Limestone, Mississippian; cuts out both conglomerate and coal nearby	..	..

Sample No. 65, reported on pages 365 and 366, includes No. 6 and part of 5 of the section.

Section at small coal opening on Mauvais Terre Creek about 4½ miles downstream from Exeter

	Thickness Ft.	In.
8. Clay shale	4	..
7. "Slate" or carbonaceous shale	2	..
6. Coal (No. 2)	2	8
5. Covered	5	4
4. Limestone, nodular; same as number 8 of previous section	4	6
3. Clay, impure, stained yellow	3	6
2. Limestone, regular bedded, with shale partings	8	8
1. Clay	unmeasured	

At outcrops two miles northeast of Alsey numerous gypsum crystals appear on the surface of four feet of clay just below the limestone.[1]

If conditions here are similar to those at Alsey, the fire clay might be expected to be of better quality east of the outcrop where it would lie at a greater depth. The record of the city well at Jacksonville, Morgan County, shows five feet of fire clay below a coal at a depth of 148 feet.

Near Franklin six feet of fire clay is reported at a depth of 347 feet.

[1]Op. cit., p. 68.

RESULTS OF TESTS

SCOTT COUNTY

Sample No. 71

(Abandoned plant at Alsey)

The sample is a hard material of a dark gray color. When tempered with water it becomes very plastic. Its conduct in flowing through a die is fair.

Water of plasticity	*per cent*	21.8
Shrinkage water	*per cent*	10.9
Pore water	*per cent*	10.9
Modulus of rupture	*lbs. per sq. in.*	328
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	144
Slaking test, average	*min.*	10

Screen test:—

Mesh	Residue *Per cent*
20	0.6
40	0.13
60	0.11
80	0.14
120	Trace
200	Trace

Drying shrinkage:—

	Per cent
Linear; dry length	5.9
Linear; wet length	5.6
Volume	21.4

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
02	16	Cream	7.1	Vanadium stain (?)
3	15	Light cream	5.3	Vanadium stain (?)
5	14	Light cream	6.0	....
6	12.7	Light cream	6.0	....
8	11.2	Light cream	....	....
9	10	Cream	6.6	....
12	....	Bluestoned; light buff outside	9	Contains fine black specks
13	1.0	Bluestoned	....	....
15	3.4	Buff exterior; bluestoned (black)	8.9	....

Fusion test:—It deforms between cones 30 and 31.

Summary

The clay has a medium strength and a medium low bonding strength. The amount of screen residues is slight. Drying shrinkage is medium and total shrinkage at cone 9 is medium high. It is practically non-porous at cone 13 and apparently shows slight overburning at cone 15. It is a refractory clay.

Suggested uses: Stoneware, architectural terra cotta, face brick, sanitary ware, refractories.

Sample No. 70

(Abandoned plant at Alsey)

This is a grayish colored clay of medium hardness. It is very plastic when tempered with water.

Water of plasticity	*per cent*	41.8
Shrinkage water	*per cent*	31.4
Pore water	*per cent*	10.4
Modulus of rupture	*lbs. per sq. in.*	609
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	302.8
Slaking test, average	*min.*	7
Drying shrinkage, linear	*per cent*	12.5

Screen test:—

Mesh	Residue *Per cent*	Character of residue
10	Trace	Hard lumps of black shale
14	Trace	Hard lumps of black shale
20	0.85	Hard lumps of black shale with particles of coal
35	6.8	
48	7.4	
65	7.4	
100	5.1	
150	8.1	
200	8.5	

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
04	20	Yellow cream	2.9	Hackly fracture
02	18	Dark cream	4.7	Hackly fracture
2	7.5	Buff cream	6.2	Hackly fracture
5	3.5	Buff cream	5.9	Hackly fracture
9	2.5	Gray; bluestoned	6.8	Hackly fracture
13	10	Light tan; bluestoned	5.6	Black core
14	9		21.5	Bloated

Fusion test:—It fuses at cone 26. Vesicular structure.

Summary

The clay has a medium high strength and medium bonding strength. The drying shrinkage is high. The total shrinkage at cone 9 is high. It is fairly well vitrified at cone 2 and is overburned at cone 13. The oxidation rate is slow.

Suggested uses: Stoneware, architectural terra cotta, sanitary ware, face brick.

Sample No. 65

(Bluff of Mauvais Terre Creek ½ mile west of Exeter)

This is a brownish colored shaly clay. It becomes very plastic when tempered with water. It flows satisfactorily through a die.

Water of plasticity	*per cent*	22.0
Shrinkage water	*per cent*	9.9
Pore water	*per cent*	12.0
Modulus of rupture	*lbs. per sq. in.*	240.8
Slaking test, average	*min.*	6

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	0.22	Colored sand
40	0.40	
60	0.77	
80	0.64	
120	2.9	
200	2.3	

Drying shrinkage:—

	Per cent
Linear; dry length	4.9
Linear; wet length	4.7
Volume	18.7

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	24	Pinkish cream	3.1	....
1	24	Pinkish cream	3.1	....
3	22	Medium cream	3.8	Fine iron specks, earthy fracture
5	21	Medium cream	4.0	....
6	21	Medium cream	4.2	Fine iron specks; earthy fracture
9	17	Light tan	4.3	Numerous fine iron specks
12	9	Darker tan	6.2	Numerous fine iron specks
13	3.5	Bluestoned	6.6	....
15	3.3	Buff exterior; bluestoned (black)	6.7	Iron spots

Fusion test:—It deforms between cones 26 and 27.

Summary

This clay has a medium strength and a medium low drying shrinkage. The total shrinkage at cone 9 is medium. It is well vitrified at cone 13 and not overburned at cone 15. It is a non-refractory clay.

Suggested uses: Stoneware, architectural terra cotta, sanitary ware, for which uses it should be washed, face brick.

PIKE COUNTY

Clay outcrops in the west bluff of Illinois River at Bedford. The relation to the Mississippian limestone at the north suggests faulting. Twenty-seven feet of clay are exposed above and 16 or more feet below. This thickness makes the deposit of special interest.

Section of the river bluff at Bedford

		Thickness Ft.	In.
7.	Loess and loose limestone blocks to top of mound	50	..
6.	Covered, cherty fragments over slope	10	..
5.	Clay, bluish gray; partly covered yellow iron stains in lower part (Sample No. 67)	27	..
4.	Covered interval	11	6
3.	Partly covered, probably clay	9	..
2.	Clay, blue (Sample No. 69)	16	6
1.	Partly covered to water level in Illinois River; loose blocks indicate Mississippian limestone in the lower part of this interval	20	..

Clay has been dug in small amounts about 2 miles north of Pittsfield and used as a blend for surface clay in making building brick and drain tile and possibly also for pottery. This deposit (sample No. 66, p. 369) is reported to vary from 6 to 13 feet in thickness. It is of a bluish white color where exposed and has an overburden of drift and loess up to 20 feet in thickness. Boring has shown that the clay extends back under the bluff over an area of several acres and the topography suggests that extensive areas are underlain by clay both to the south and east.

RESULTS OF TESTS—PIKE COUNTY

Sample No. 67

(West bluff of Illinois River at Bedford)

This is a gray colored, soft clay which develops a good plasticity.

Water of plasticity	*per cent*	26.5
Shrinkage water	*per cent*	12.5
Pore water	*per cent*	14.0
Modulus of rupture	*lbs. per sq. in.*	303.8
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	248.7
Slaking test, average	*min.*	15

Screen test:—

Mesh	Residue *Per cent*	Character of residue
40	0.12	Quartz sand, and pyrite
60	0.4	Quartz sand, and pyrite
80	Trace	....
120	0.3	Sand and some pyrite
200	0.3	Sand and some pyrite

Drying shrinkage:—

	Per cent
Linear; dry length	6.4
Linear; wet length	6.0
Volume	23.9

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
04	25.4	Terra cotta	2.1	...
02	16.6	Light red brown	4.8	...
2	6.7	Brown	7.4	Hackly fracture
5	2	Brown-red	5.6	Vitreous, appears to be overburned
9	2.7	Brown-red	...	Overburned badly

Fusion test:—It fused to glass at cone 25.

Summary

The clay has a medium strength and a medium bonding strength. The drying shrinkage is medium. The total shrinkage at cone 5 is medium low. At cone 9 the sample is overburned. It is a non-refractory clay.

Suggested uses: Face brick, sewer pipe, hollow block, paving brick (?).

Sample No. 69

(West bluff of Illinois River at Bedford)

This is a clay of a uniform gray color, containing some shaly particles. It is very plastic when tempered with water. The flowing conduct of the clay when forced through a die is satisfactory.

Water of plasticity	*per cent*	24.7
Shrinkage water	*per cent*	13.5
Pore water	*per cent*	11.2
Modulus of rupture	*lbs. per sq. in.*	498.3
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	242.0
Slaking test, average	*min.*	14

Screen test:—

Mesh	Residue *Per cent*
20	None
40	Trace
60	0.3
80	Trace
120	0.2
200	0.2

Drying shrinkage:—

	Per cent
Linear; dry length	6.6
Volume	26

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
04	26 5	Terra cotta	4.8	Hackly fracture
02	14.4	Terra cotta	4.9	Hackly fracture
2	1.8	Reddish brown	7.6	Hackly fracture
5	24	Reddish brown	...	Overburned
9	19.9	Red-brown	...	Swelled

Fusion test:—Bloated and fell over before cone 8 in a Fletcher furnace.

Summary

This clay has a medium high strength, a medium bonding strength, and a medium drying shrinkage. The total shrinkage at cone 2 is medium; vitrification proceeds rapidly and is practically complete at cone 2. It is overburned at cone 5.

Suggested uses: Common brick, drain tile.

Sample No. 66

(2 miles north of Pittsfield)

This is a soft clay, colored yellow to dark brown. A fair degree of plasticity may be developed.

Water of plasticity	*per cent*	27
Shrinkage water	*per cent*	13.5
Pore water	*per cent*	13.5
Modulus of rupture	*lbs. per sq. in.*	414.5
Slaking test, average	*min.*	11

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	0.08	Rock particles and organic matter
40	Trace	......
60	Trace	......
80	Trace	......
120	0.79	White sand and rootlets
200	1.32	White sand and rootlets

Drying shrinkage:—

	Per cent
Linear; dry length	8.2
Volume	24.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	17	Cream	4.9	......
2	14	Cream	5.1	......
3	12	Medium cream	5.8	Smooth fracture; fine iron specks (?); none on another trial piece
6	6	Medium cream	6.2	Smooth fracture; fine iron specks (?); none on another trial piece Somewhat conchoidal fracture
9	1.2	Stoneware gray	6.3	Vitreous

12	1.0	Gray white	5.0	Fine veining of iron stain; good color
13	1.6	Gray white	4.5	....
15	3.8	Gray white	4.5	Fine iron spots

Fusion test:—It deformed at cone 29.

Summary

The sample is a clay of medium high strength which has a medium drying shrinkage. The total shrinkage at cone 9 is medium high. Vitrification is practically complete between cones 6 and 9. There are some indications of overburning at cone 15. It is a refractory clay.

Suggested uses: Stoneware, architectural terra cotta, sanitary ware, a plastic bond for refractories.

ADAMS COUNTY

Toward the west the basal clays of the Pennsylvanian contain more gypsum, and are generally streaked by yellowish and buff iron markings. In a road cut 2½ miles north and one mile west of Camp Point, 8½ feet of distinctly bedded clay are exposed. The upper 2½ feet are tough, ash colored clay, containing much gypsum sand and small gypsum crystals, and colored by streakings of iron. An overburden of from 5 to 15 feet of gravel and clayey till with locally thin sandstone layers immediately above the clay, forms the covering.

BROWN COUNTY

On Crooked Creek in the vicinity of Ripley, clay has been dug for stoneware. The old pits one mile south of Ripley are almost obliterated by surface wash and caving. Since the clay directly underlies the drift it does not promise to be of refractory value.

SCHUYLER COUNTY

At a small mill and kilns at Frederick, drain tile is manufactured from a mixture of surface clay and bedded Coal Measures clay.

Section of the clay pit at Frederick

	Thickness Ft.	In.
5. Loess	9	..
4. "Potter's clay"	8	..
3. Coal ("peacock vein")	3	3
2. Clay, drab and sandy; plant remains and yellow iron stains	10	..
1. Shale, blue	..	..

MC DONOUGH COUNTY

"The line of outcrop of the clay in McDonough County extends along the bluffs and ravines of the east fork of Crooked Creek from Bardolph to the county line on the north side and Tennessee on the south side, whence it extends southeast toward Schuyler County."[1] Clay is being dug about

[1] Op. cit., p. 70.

Colchester and from a pit about 3 miles northeast of Macomb.

At the open pit of the Macomb Sewer Pipe Works about 3 miles northeast of Macomb the clay is stripped, loaded by steam shovel, and hauled over a standard gauge track to the plant at Macomb. Samples No. 73a, No. 73b, and No. 73c are respectively from the top, middle and bottom of a boring on the Company's property. Results of tests are given on pages 373 and 374. A section of the face of the pit is as follows:

Section of the face of the pit of the Macomb Sewer Pipe Works, 3 miles northeast of Macomb

	Thickness *Feet*
6. Loess, drift, and soil	20 to 25
5. Sandstone, hard, and chert	6
4. Coal traces	..
3. Clay, used for sewer pipe	10
2. Pebbles and iron concretions in layer	..
1. Shale, dark blue	10+

The Colchester Brick and Tile Company uses the clay from this horizon at its plant near Colchester in the manufacture of refractory brick, tile, and silo blocks. The clay is dug from an open pit in the side of a hollow (fig. 54) and hauled by wagon to the mill.

Section of Colchester Brick and Tile Company's pit, half a mile north of Colchester

	Thickness *Ft.*	*In.*
7. Shale, sandy	20	..
6. Shale, dark, and coal	2	..
5. Fireclay, poor grade	3	..
4. Shale, dark	..	6
3. Fireclay, stained yellow by iron (Sample No. 75a)	6	..
2. Shale	7	..
1. Fireclay (Sample No. 75b)	10	..

Sample No. 75a is from No. 3, and sample No. 75b from No. 1 of the above section. Results of tests are given on pages 374 to 376.

Most of the clay obtained about Colchester is taken from mines west of town. The clay taken from the shaft of the Gates Fireclay Company is used for making flue linings among other clay products.

Log of shaft at the Gates Fireclay Company's mine, near Colchester

Description of strata	Thickness *Feet*	Depth *Feet*
Soil and glacial clay	24	24
"Soapstone," compact shale	26	50
Coal (No. 2)	2½	52½
Fireclay, used in the manufacture of flue linings, etc., "upper vein" (Sample No. 88, see pages 376-377)	5½	58

Log of Gates Fireclay Company's mine shaft—Continued

Limestone, scattered boulders	..	..
"Hard rock," probably sandstone	6	64
Clay, "middle vein"	8	72
Sandstone	5	77
Shale	8	85

The firm of Baird Brothers is operating a mine one mile northwest of Colchester in a 7- to 8-foot bed of clay that lies below the "middle vein" of the Gates shaft. On the Valentine farm three drift tunnels have been opened into a 7- to 8-foot bed of clay, and about 150 tons are taken out

FIG. 54. View of the Colchester Brick and Tile Company's pit half a mile north of Colchester showing No. 2 coal near the top and stoneware clay at the base.

per day. One hundred and twenty acres of the adjoining Forncuff farm are underlain by the lower and upper clay. The middle clay contains so many boulders that it cannot be worked profitably. The clay is hauled by steam locomotive over a tram to tipple at the Chicago, Burlington and Quincy Railroad at Colchester.

Sample No. 74 (p. 377) is from south mine, and sample No. 78 (p. 378) from the north mine on the Valentine farm. Sample No. 75 (p. 379) was taken from a carload of clay as it came from the Meyers mine, west of the Baird mines.

Two other mines were being operated in June, 1918; one 3 miles west of town in the same bed as are the above mines, another 2½ miles west where the No. 2 coal and the underlying clay are both recovered.

RESULTS OF TESTS

MCDONOUGH COUNTY

Sample No. 73-a

(Macomb Sewer Pipe Works; 3 miles northeast of Macomb)

The sample is a gray shaly material, containing many mica flakes. It becomes very plastic when worked with water.

Water of plasticity	*per cent*	28.3
Shrinkage water	*per cent*	12.9
Pore water	*per cent*	15.4
Modulus of rupture	*lbs. per sq. in.*	352.2
Slaking test, average	*min.*	13

Drying shrinkage:—

	Per cent
Linear; dry length	6.5
Volume	22.9

Burning test:—

Cone	Porosity	Color	Total shrinkage
	Per cent		*Per cent*
1	16	Cream	10.6
5	10	Cream	12.4
9	4.8	Light gray	13.1
15	2.1	Light gray	10.0

Fusion test:—Cone slightly deformed at cone 26. Vesicular at cone 27.

Summary

The clay has a medium strength. The drying shrinkage is medium and the total shrinkage at cone 9 is medium high. It has a low porosity at cone 9 and has only a slight porosity at cone 15. It is non-refractory.

Suggested uses: Stoneware, architectural terra cotta, sanitary ware, face brick.

Sample No. 73-b

(Macomb Sewer Pipe Works; 3 miles northeast of Macomb)

This is a rather hard clay, varying in color from a light to a dark gray. When tempered with water it becomes very plastic and flows satisfactorily through a die.

Water of plasticity	*per cent*	24.9
Shrinkage water	*per cent*	11.9
Pore water	*per cent*	13.0
Modulus of rupture	*lbs. per sq. in.*	356.5
Slaking test, average	*min.*	9

Drying shrinkage:—

	Per cent
Linear	6.2
Volume	21.8

Burning test:—

Cone	Porosity	Color	Total shrinkage	Remarks
	Per cent		*Per cent*	
1	10.9	Light brown	13.7	Poorly oxidized
5	5.1	Brown	14.0	....
9	0.4	Dark brown	12.5	....
15	0.0	Dark gray	11.2	Overburned, beginning to bloat

Fusion test:—At cone 26 the cone was deformed half way and showed many bubbles on the surface.

Summary

The strength is medium. The drying shrinkage is medium. Burning shrinkage at cone 9 is medium. It burns to a dense body at cone 5 and is practically non-porous at cone 9. At cone 15, signs of overburning appear. It is non-refractory.

Suggested uses: Sewer pipe, face brick, possibly paving brick.

Sample No. 73-c

(Macomb Sewer Pipe Works; 3 miles northeast of Macomb)

This is a hard dark gray-colored. clay which develops a very good plasticity.

Water of plasticity	*per cent*	26.8
Shrinkage water	*per cent*	10.5
Pore water	*per cent*	16.3
Modulus of rupture	*lbs. per sq. in.*	339.3
Slaking test, average	*min.*	9

Drying shrinkage:—

	Per cent
Linear	7.0
Volume	16.8

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
1	11.2	Cream	12.5	....
5	4.0	Cream	14.4	Conchoidal vitreous fracture
9	0.2	Gray	14.4	Conchoidal vitreous fracture
15	0.8	Gray	11.2	Conchoidal vitreous fracture

Fusion test:—⅓ deformed at cone 27. Vesicular.

Summary

The clay has a medium strength. The drying shrinkage is medium and the total shrinkage at cone 9 is medium high. It attains a low porosity at cone 5 and is completely vitrified between that and cone 9. It is a refractory clay.

Suggested uses: Stoneware, architectural terra cotta, face brick, sanitary ware, and some types of refractories.

Sample No. 75-a

(Colchester Brick and Tile Company's pit; ½ mile north of Colchester)

This is a clay which is not of a uniform color, varying from gray to yellowish brown. The gray portions are harder than the yellow. Tempered with water, it develops a medium plasticity. When squeezed through a die, it flows rather badly.

Water of plasticity	*per cent*	25
Shrinkage water	*per cent*	7.6
Pore water	*per cent*	17.3
Modulus of rupture	*lbs. per sq. in.*	269.6
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	192
Slaking test, average	*min.*	4

Screen test:—

Mesh	Residue Per cent	Character of residue
40	0.2	White and colored sand
60	1.4	White and colored sand
80	0.3	White and colored sand
120	3.3	White and colored sand and mica
200	3.7	White and colored sand and mica

Drying shrinkage:—

	Per cent
Linear; dry length	4.7
Linear; wet length	4.5
Volume	11.2

Burning test:—

Cone	Porosity Per cent	Color	Burning shrinkage Per cent	Remarks
04	33	Light red	1.0	......
02	30	Light red	1.7	......
5	23.3	Dark tan	4.4	Hackly fracture
9	13.5	Brown	8.2	Hackly fracture
13	16.9	......	...	Overburned

Fusion test:—It fused completely at cone 26.

Summary

The clay has a medium strength, a medium low bonding strength, a medium low drying shrinkage, and a medium high total shrinkage at cone 9. Minimum porosity—13.5%—is attained at cone 9 and overburning appears at cone 13. It is a non-refractory clay.

Suggested uses: Brick, tile.

Sample No. 75-b

(Colchester Brick and Tile Company's pit; ½ mile north of Colchester)

This is a hard gray-colored clay, having an irregular fracture. When tempered with water, it develops a good plasticity and flows well through a die.

Water of plasticity	*per cent*	20.0
Shrinkage water	*per cent*	8.6
Pore water	*per cent*	11.4
Modulus of rupture	*lbs. per sq. in.*	263
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	199.6
Slaking test, average	*min.*	8

Screen test:—

Mesh	Residue Per cent	Character of residue
20	0.3	Rock particles
40	0.9	Rock particles and quartz sand
60	2.1	Rock particles and quartz sand
80	0.3	Rock particles and quartz sand
120	1.4	Quartz sand and mica
200	2.2	Quartz sand and mica

Drying shrinkage:—

	Per cent
Linear	4.8
Volume	16.5

Burning test:—

Cone	Porosity	Color	Burning shrinkage	Remarks
	Per cent		Per cent	
04	30	White	0.1	
02	28	Cream	0.5	
2	25.5	Cream	1.7	Hackly fracture
5	25.0	Cream	2.0	Hackly fracture
9	17.4	Gray white	3.0	A very few fine iron spots
13	6.3	Stoneware gray	5.2	Many slagged iron spots
14	6.8	Buff	2.7	

Fusion test:—Completely deformed at cone 26. Not fused as much as 75-a.

Summary

The strength of the clay is medium. Its bonding strength is medium. The drying shrinkage is medium low and total shrinkage at cone 9 is medium. The porosity is low at cone 14 but vitrification is incomplete. It is a non-refractory clay.

Suggested uses: Stoneware, architectural terra cotta, sanitary ware, face brick.

Sample No. 88

(Gates Fireclay Company's mine, near Colchester)

This is a dark colored, very hard clay, which becomes very plastic when tempered with water.

Water of plasticity	*per cent*	27.7
Shrinkage water	*per cent*	11.7
Pore water	*per cent*	15.9
Modulus of rupture	*lbs. per sq. in.*	496
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	243
Slaking test, average	*min.*	14

Screen test:—

Mesh	Residue	Character of residue
	Per cent	
20	None	
40	Traces	
60	0.29	Dark red grains
80	0.2	
120	2.8	
200	1.0	

Drying shrinkage:—

	Per cent
Linear; dry length	7.2
Linear; wet length	6.7
Volume	28

Burning test:—

Cone	Porosity	Color	Burning shrinkage	Remarks
	Per cent		*Per cent*	
01	0.8	Tan	7.7	Vitreous fracture
2	0.6	Darker tan	7.6	Vitreous fracture
3	0.5	Grayish tan	7.3	Vitreous fracture
4	0.7	Grayish tan	6.9	Vitreous fracture
6	0.8	Dark gray	6.9	Vitreous fracture
9	2.6	Stoneware gray	7.3	Numerous fine iron spots; vitreous fracture
12	4.4	Bluestoned, surface flashed	4.0	Numerous fine iron spots; vitreous fracture
13	2.2	Buff exterior	2.6	Many fine iron spots; blue core

Fusion test:—Partly deformed at cone 27.

Summary

The strength of the unburned clay is medium and its bonding strength is medium. The amount of residue on the sieve is low. The drying shrinkage is medium and the total shrinkage when burned at cone 9 is medium high. It is practically non-porous at cone 01 which is an unusually low temperature and shows distinct over-burning at cone 13. The sample burned at that temperature appears to be reduced. It is a refractory clay.

Suggested uses: Stoneware, architectural terra cotta, refractories (particularly when good bonding properties are required), sanitary ware, face brick.

Sample No. 74

(Valentine farm, south mine; near Colchester)

This is a dark gray colored clay which becomes very plastic upon the addition of water.

Water of plasticity	*per cent*	22.0
Shrinkage water	*per cent*	8.0
Pore water	*per cent*	14.0
Modulus of rupture	*lbs. per sq. in.*	221.8
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	214.9

Screen test:—

The sample would not slake satisfactorily for this test.

Slaking test, average ... *min.* 8

Drying shrinkage:—

	Per cent
Linear; dry length	4.8
Linear; wet length	4.6
Volume	15.0

Burning test:—

Cone	Porosity	Color	Burning shrinkage	Remarks
	Per cent		*Per cent*	
1	21	Cream	2.2	....
2	20	Cream	2.3	....

3	20	Cream	2.3	Fine iron speck
6	17.9	Slightly darker	3.2	Fine iron speck
9	13.4	Cream	3.5	Fine iron speck
12	9.0	Cream	4.0	Numerous quartz grains; fine iron spots
13	4.1	Buff	4.4	Iron spots, small; slagged
15	3.9	Bluestoned; buff exterior	4.3	Slagged iron spots

Fusion test:—Cone half way down at cone 26.

Summary

The clay has a medium strength and medium bonding strength. Drying shrinkage is medium low and total shrinkage at cone 9 is medium. It is non-refractory.

Weathering or aging will improve its working properties.

Suggested uses: Face brick, stoneware, and terra cotta. But its slow slaking character as noted under the screen test may limit its usefulness for the latter purposes.

Sample No. 78

(Valentine farm, north mine; near Colchester)

This is a hard dark gray colored clay which may be brought to a very plastic condition. Its conduct when flowing through a die is very good.

Water of plasticity	*per cent*	19.
Shrinkage water	*per cent*	9.4
Pore water	*per cent*	9.6
Modulus of rupture	*lbs. per sq. in.*	325.8
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	209.4
Slaking test, average	*min.*	7

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	0.8	Hard clay and rock particles
40	0.7	Hard clay and rock particles, also pyrite
60	0.7	Hard clay and rock particles, also pyrite
80	0.22	Hard clay and rock particles, also pyrite
120	0.75	Hard clay and sand
200	0.7	Hard clay and sand

Drying shrinkage:—

	Per cent
Linear; dry length	4.1
Linear; wet length	4.0
Volume	16.9

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
01	23	Cream white	2.8	Granular fracture
1	23	Cream white	2.6	Granular fracture
3	20	Cream white	3.3	Granular fracture
6	18	Cream white	4.0	Granular fracture
8	18	Cream	...	Granular fracture

9	14.9	Cream	4.0	....
12	9.0	Dark cream or light tan	5.2	Earthy fracture. Numerous fine iron specks. Also quartz grains.
15	6.5	Buff exterior; bluestoned	7.2	Numerous iron spots. Slagged.

Fusion test:—No deformation at cone 25. It deforms at cone 29.

Summary

The strength of the unburned clay is medium. Its bonding strength is medium. The drying shrinkage is medium low. The total shrinkage at cone 9 is medium. A low porosity is not reached until cone 15. It is a refractory clay.

Suggested uses: Architectural terra cotta, stoneware, sanitary ware, refractories, and face brick.

Sample No. 75

(Meyers mine; near Colchester)

This is a very hard dark gray clay which slakes very slowly. However, when properly worked with sufficient water, it develops a fair degree of plasticity and may be forced through a die satisfactorily.

Water of plasticity	*per cent*	20.7
Shrinkage water	*per cent*	9.1
Pore water	*per cent*	11.6
Modulus of rupture	*lbs. per sq. in.*	295.6
Slaking test, average	*min.*	8

Drying shrinkage:—

	Per cent
Linear; dry length	4.9
Linear; wet length	4.7
Volume	17.6

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	20	Cream	2.8	....
2	17.3	Cream	4.7	....
5	13.8	Cream	8.3	....
9	6.8	Cream	11.0	Fine iron spots
12	2.5	Gray white	11.5	Fine iron spots
13	1.5	Grayish white	10.5	Numerous iron spots, small
15	4.0	Grayish white	....	Numerous iron spots; slagged

Fusion test:—No deformation at cone 30. No vesicular structure.

Note:—The iron (?) spots are so black as to suggest the presence of manganese. Its unusual appearance may be due to reduction. The effect at higher cones is very unique and interesting.

Summary

The clay has a medium strength. The drying shrinkage is medium low. Total shrinkage at cone 9 is medium high. Minimum porosity. Complete vitrification is

reached at cone 13. At cone 15 the slight increase in porosity may indicate incipient overburning. It is a refractory clay.

Suggested uses: The appearance of numerous fine slagged spots at the high temperatures raises a question as to the desirability of this as a material for refractories. Its slow slaking character lessens its value in some degree for stoneware and architectural terra cotta. However, weathering or aging will correct these difficulties.

FULTON COUNTY

A sample of clay (No. 84) from about a mile northwest of Avon was taken at the Avon Milling and Manufacturing Company's plant at Avon. The clay had been dug from the bed of Swan Creek and is used for refractory linings about the boiler.

RESULTS OF TESTS

FULTON COUNTY

Sample No. 84

(Avon Milling and Manufacturing Company, at Avon.)

The clay is a dark gray color with darker patches due to the presence of carbonaceous matter. Its plasticity is only fair and its conduct in flowing through a die is fair.

Water of plasticity	*per cent*	21.5
Shrinkage water	*per cent*	9.0
Pore water	*per cent*	12.4
Modulus of rupture	*lbs. per sq. in.*	214
Slaking test, average	*min.*	4½

Screen test:—

Mesh	Residue *Per cent*	Character of residue
40	0.5	Sand and coal
60	3.2	Sand and coal
80	0.4	Sand and coal
120	2.3	Sand and coal
200	11.6	White sand, mica, and coal

Drying shrinkage:—

	Per cent
Linear; wet length	3.7
Linear; dry length	3.8
Volume	17

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	26	Light tan	1.8	Granular fracture
3	26	Light tan	1.9	Granular fracture
6	25	Light tan	2.6	Granular fracture
9	20	Light tan	3.7	Granular fracture
13	11.6	Buff	5.5	Fine iron (?) spots
15	16.6	Buff	5.8	Fine iron (?) spots

Fusion test:—The cone fused to a glass at cone 28.

Summary

The strength of the clay is medium. There is a considerable amount of residue left on the screens. The drying shrinkage is medium low, and when burned at cone 9, the total shrinkage is medium low. Vitrification is incomplete at cone 13 and it is overburned at cone 15. It is a non-refractory clay.

Suggested uses: Architectural terra cotta, face brick. It appears to be rather short for stoneware.

MERCER COUNTY

The Northwestern Clay Manufacturing Company formerly recovered small amounts of clay with the No. 1 coal at their pits near Griffin. A sample was taken from clay which had been drawn from below the No. 1 coal at that time. The shale, till, and overlying soil are used for sewer pipe.

Section of the Northwestern Clay Manufacturing Company's pit at Griffin

	Thickness Ft.	In.
6. Soil and yellow clay	10	..
5. Shale (Sample No. 86)	25 to 30	..
4. Limestone	2	..
3. "Potter's clay," thin horizon	unmeasured	
2. Coal (No. 1)	2	5
1. Clay (Sample No. 85)	6	..

RESULTS OF TESTS

MERCER COUNTY

Sample No. 86

(Northwestern Clay Manufacturing Company's pit, at Griffin)

The material is a hard grayish-colored, shaly clay, streaked with brown and black. The plasticity is fair.

Water of plasticity	*per cent*	29.5
Shrinkage water	*per cent*	21.9
Pore water	*per cent*	7.6
Modulus of rupture	*lbs. per sq. in.*	190.2
Slaking test, average	*min.*	6

Screen test:—

Mesh	Residue *Per cent*	Character of residue
10	2.2	Particles of shale, grains of coal
14	1.7	
20	2.4	
35	3.2	
48	0.6	
65	0.4	
100	1.1	
150	1.0	Shale with mica
200	1.5	Shale with mica

Drying shrinkage:—

	Per cent
Linear; dry length	3.62
Linear; wet length	3.5

Burning test:—

Cone	Porosity Per cent	Color	Burning shrinkage Per cent	Remarks
02	18.4	Dark red	5.0	Hackly fracture
5	14.5	Dark red	8.5	....
9	0.5	Dark red	9.4	Vitreous fracture
12	....	....	...	Bloated

Fusion test:—It fused completely at cone 27.

Summary

The drying shrinkage is medium low. The strength is medium low. The total shrinkage at cone 9 is medium high. The shale reaches a minimum porosity at or before cone 9 and overburns beyond that point.

Suggested uses: Sewer pipe, brick, tile, etc.

Sample No. 85

(Northwestern Clay Manufacturing Company's pit, at Griffin)

The sample is a soft clay of a gray color with darker mottling. Its plasticity is very good when tempered with water.

Water of plasticity .... per cent 28.8
Shrinkage water .... per cent 11.9
Pore water .... per cent 17.0
Modulus of rupture .... lbs. per sq. in. 386.7
Slaking test, average .... min. 4½

Screen test:—

Mesh	Residue Per cent	Character of residue
10	7.0	Particles of coal and shale
14	6.5	
20	8.9	
35	13.8	
48	3.7	
65	5.4	
100	3.9	
150	2.4	Particles of coal and shale, with flakes of mica
200	2.6	

Drying shrinkage, linear .... per cent 6.5
Volume .... per cent 21

Burning test:—

Cone	Porosity Per cent	Color	Total shrinkage Per cent	Remarks
02	14.4	Cream	13.4	....
1	6.7	Cream	14.6	....
3	0.5	Gray	15.9	Vitrified
5	0.8	Dark gray	16.2	Bluestoned
7	1.2	Dark gray	13.6	Bluestoned; slightly vesicular
9	1.4	Dark gray	11.1	Bluestoned; slightly vesicular
13	1.6	Dark gray	7.5	Bluestoned; slightly vesicular

Fusion test:—Completely deformed at cone 26. Vesicular.

Summary

The strength of the clay is medium. The quantity of screen residues is high. The drying shrinkage is medium. The total shrinkage at cone 5 is medium high. Complete vitrification is attained at a very low cone and the incipient overburning which seems to appear at cone 9 does not become serious even at cone 16. The appearance of the pieces suggests reducing conditions during the burn. The appearance of a whitewash on the pieces burned at cone 7 or lower should be noted. It is non-refractory.

Possible uses: Architectural terra cotta, paving brick, stoneware, sanitary ware, sewerpipe, conduits.

ROCK ISLAND COUNTY

A sample was taken from the clay above No. 1 coal at Sears (sample No. 83). The clay below that coal was covered by water when visited. A second sample was taken from white clay lying directly below the No. 1 coal (sample No. 81); ordinarily a 5-foot sandstone commonly separates this clay and the coal but here it is missing. The clay[1] is full of pyrite concretions which weather to limonite at the surface. The plant which formerly operated here is now idle and the pits are in bad condition.

Results of tests on samples No. 83 and No. 81 are given on pages 383 and 384.

A large part of the upper 40 feet of the overburden which is a fine loess of pure quartz sand is now used for moulding sand. The value of the overburden in this case would materially reduce the cost of obtaining the clay if it were to be worked from an open cut. The maximum overburden would be nearly 60 feet.

At Carbon Cliff the fine clay (Cheltenham) varies from 10 to 25 feet in thickness, being replaced where the lesser thickness is found by as much as 10 feet of black shale which apparently wedges out laterally into the clay. The clay shows iron stains and traces of red. At its base there is a layer of nodular impure limestone boulders and limonite concretions. The overburden of 18 to 25 feet could be removed most economically, it is believed, by a steam shovel.

Sample No. 79 was taken from the west bank and sample No. 80 from the working face in the east pit. Results of tests are on page 385.

RESULTS OF TESTS

ROCK ISLAND COUNTY

Sample No. 83

(Clay above No. 1 coal at Sears)

This is a medium hard clay which is colored gray, heavily mottled with brown. The plasticity is very good when it is tempered with water and it flows satisfactorily through a die.

Water of plasticity	*per cent*	28.7
Shrinkage water	*per cent*	16.4
Pore water	*per cent*	12.2

[1]According to Lines, Op. cit., this clay was formerly used for sewer pipe.

Modulus of rupture, maximum	*lbs. per sq. in.*	768
minimum	*lbs. per sq. in.*	664
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	329
Slaking test, average	*min.*	11½

Drying shrinkage:—

	Per cent
Linear; dry length	7.5
Linear; wet length	7.0
Volume	31.2

Burning test:—

Cone	Porosity	Color	Burning shrinkage	Remarks
	Per cent		*Per cent*	
04	28.0	Pinkish red	1.0	
02	15.0	Pinkish tan	5.1	Hackly fracture
2	1.1		6.7	Hackly fracture
5	2.2	Dark tan	6.8	Glossy fracture
9	1.6	Dark tan	6.5	Smooth vitreous fracture
13	12.0	Gray	4.5	Overburned

Fusion test:—It entirely fused at cone 27.

Summary

The strength of the clay is medium high and its bonding strength is medium. The drying shrinkage is medium. The total shrinkage at cone 9 is medium. Vitrification proceeds very rapidly between cones 02 and 2, at which temperature it is practically complete. It is overburned between cones 9 and 13. It is non-refractory.

Suggested uses: Face brick, paving brick, sewer pipe, drain tile. The color of the burned material is rather dark for stoneware or terra cotta.

Sample No. 81

(Clay below No. 1 coal at Sears)

This is a soft gray colored clay, streaked with brown and containing a few black spots. It contains much mica.

Water of plasticity	*per cent*	22.6
Shrinkage water	*per cent*	9.8
Pore water	*per cent*	12.7
Slaking test, average	*min.*	8

Drying shrinkage:—

	Per cent
Linear	5.2
Volume	17.8

Burning test:—

Cone	Porosity	Color	Total shrinkage	Remarks
	Per cent		*Per cent*	
1	13.7	Brown	8.7	
5	6.1	Dark brown	11.8	
9	2.4	Dark brown	11.2	
15	...		....	Bloated badly

Fusion test:—Completely fused at cone 26 to brown glass showing a partly vesicular structure.

Summary

The drying shrinkage is medium low and vitrification is practically complete at cone 9. It is overburned between that cone and cone 15. It is non-refractory.

Suggested uses: Brick, tile.

Sample No. 79

(West bank at Carbon Cliff)

This is a soft clay having a dark gray color with some brown streaks. When tempered with water it becomes very plastic. It flows fairly well through a die.

Water of plasticity	*per cent*	21.7
Shrinkage water	*per cent*	8.9
Pore water	*per cent*	12.5
Modulus of rupture	*lbs. per sq. in.*	287.3
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	119.5
Slaking test, average	*min.*	4

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	Trace	....
40	Trace	....
60	Trace	....
80	Trace	....
120	Trace	....
200	1.8	Sand and mica

Drying shrinkage:—

	Per cent
Linear: dry length	6.6
Linear; wet length	6.2
Volume	17.4

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
04	32	Cream	0.0	....
02	32	Cream	1.0	Hackly fracture
2	28	Cream	1.5	Hackly fracture
5	28	Cream	2.0	Hackly fracture
9	23	Cream	3.1	Hackly fracture
13	18	Cream	3.6	Granular fracture
14	6	Brown exterior; bluestoned	2.8	....

Fusion test:—It fuses entirely at cone 26. No vesicular structure.

Summary

The clay has a medium strength and a medium low bonding strength. The drying shrinkage is medium and the total shrinkage at cone 9 is medium. The clay is very open burning until cone 14 is reached. It is non-refractory.

Suggested uses: Architectural terra cotta, stoneware, sanitary ware, and face brick.

Sample No. 80

(East pit at Carbon Cliff)

This is a clay of a medium degree of hardness, colored gray with a darker mottling. It develops a good degree of plasticity when tempered with water and flows satisfactorily through a die.

Water of plasticity	*per cent*	20.5
Shrinkage water	*per cent*	9.2
Pore water	*per cent*	11.3
Modulus of rupture	*lbs. per sq. in.*	445.4
Slaking test, average	*min.*	10½
Drying shrinkage, linear	*per cent*	6.2
Volume	*per cent*	17.7

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
02	20.7	Cream	7.2	....
1	19.7	Cream	7.5	....
3	16.4	Cream	8.1	Hackly fracture
5	13.4	Gray	8.6	Hackly fracture
8	10.4	Gray	10.0	....
9	7.2	Gray	9.8	Vitrified; hackly fracture
13	7.5	Gray	9.7	Conchoidal fracture

Fusion test:—Test pieces are ⅔ deformed at cone 26 and slightly vesicular.

Summary

The clay has a medium high strength and medium shrinkage at cone 9. The total shrinkage is medium. Vitrification is still incomplete at cone 13. The clay borders on the refractory type.

Suggested uses: Stoneware, architectural terra cotta, refractories, face brick.

LA SALLE COUNTY

At the pits of the Utica Firebrick and Clay Company two miles south of Utica the section is variable, but a somewhat generalized section of the east pit (fig. 55) is as follows:

Sections of the east pits of the Utica Firebrick and Clay Company 2 miles south of Utica

	Thickness *Ft.*	*In.*
6. Overburden, glacial drift and soil	12	..
5. Coal (No. 1)	1	6
4. Clay, blue, "Joliet clay" (Sample No. 87, p. 393); the upper foot contains numerous pyrite concretions, and similar concretions are found in the lower beds	3	6
3. Clay, green	..	8
2. Clay, gray, jointed (Sample No. 77, p. 394); used for fire brick; the upper 3 feet has a few small pyrite seams and concretions (av. 8 ft.); at one place 2 feet of the residual basal clay is lighter in color grading into a darker clay above	4	10
1. Sandstone, St. Peter; forms the "nigger heads" of the mines; the surface of the sandstone is very uneven and in one place rises so that the clay is only 1½ feet thick	..	..

A second section of East pit of the Utica Firebrick and Clay Company

		Thickness Feet
3.	Soil and drift	2 to 5
2.	Clay, dark gray with scattered pebbles and some conglomerate	10±
1.	Conglomerate, highly weathered, heavy	..

Sample No. 82 from the east pit was lost in transit, and H. E. Culver of the Survey staff visited the pit later with the intention of taking a sub-

FIG. 55. View of the Utica Firebrick and Clay Company's pit south of Utica; No. 2 coal overlies the clay.

stitute sample. Being unable to find the exact location from which sample No. 82 had been taken, he measured the following section and took sample No. C 82; results of tests are given on pages 126 and 127.

Section of West pit of the Utica Firebrick and Clay Company, near Utica

4.	Overburden, soil and drift	2 to 5
3.	Clay, gray, yellow when first exposed, very tough	2 to 3
2.	Clay, darker yellow, "putty clay" (Sample No. 82); chert concretions and pyrite at base	5 to 6
1.	Sandstone; very much hardened by iron at surface	..

The clay is hauled by train from the pit to a tipple, dumped down onto a tram at river level, transferred across the Illinois River by barge and then taken by train to the plant at Utica.

About 20 acres has been tested by drilling beyond the borders of the present pits.

The plant can produce from 12,000 to 20,000 fire brick per day and about 30 tons of ground fireclay is shipped every month as well as crude clay in varying amounts up to 1000 tons. Small lots of the yellow "putty" clay have been shipped for ochre but most of it is used as furnace lining. A boring between the two pits has shown that the "putty" clay overlies the better grade blue clay.

M. J. Gorman and Company are operating an open pit in sec. 21, T. 22 N., R. 1 E. The clay is hauled 1½ miles by team and wagon to Utica. The average production is about 10,000 tons per year, including both "putty" and blue clay.

Section of M. J. Gorman and Company's pit 1½ miles south of Utica

	Thickness Ft.	In.
9. Soil	1	..
8. Soil and drift	6	..
7. Coal (No. 2), absent over parts of the clay	3	..
6. Clay, yellow and blue, very plastic, scattered gypsum crystals; "putty clay" (Sample No. 97, pp. 395-396)	4	..
5. Clay, green	..	6
4. Clay, blue (Sample No. 100, pp. 396-397)	9	..
3. Pyrite, large boulders, usually with calcareous centers	..	..
2. Clay, blue	5	..
1. Sandstone, probably St. Peter	..	..

Sample No. 98 was taken from the side of a gully a few rods up-stream from the mouth of the clay pit. It lies, however, below the mouth of the pit in altitude. This is not worked, and the sample was taken from a 2′ x 4′ x 3″ cut on the sloping surface of the clay bank which lies beneath soil and above sandstone which is probably St. Peter, but may be the lower sandstone of the Pennsylvanian. See page 397 for results of tests.

More than seventy acres of clay have been proved by boring.

The Company is contemplating tractor and trailer haulage over the 1½ miles of paved road to the railroad at Utica.

The Illinois Clay Products Company are producing 250 to 300 tons of ground fireclay per day, from their mine at Deer Park.

Only the upper 6 or 7 feet is mined at the present time, as it is found impracticable to mine a greater thickness.

Section of Illinois Clay Products Company's mine at Deer Park

	Thickness Ft.	In.
10. Overburden, of glacial till and soil	unmeasured	
9. "Soapstone," compact, sandy clay shale	15±	..
8. Coal (No. 2); forms roof of mine	3	6
7. Clay (Sample No. 93, p. 398); only the upper 6 to 7 feet mined at present; erratic lenses of sandrock at the bottom of the present workings; pyrite nodules about 3 feet from the top of the clay, also large pisolitic boulders; in part of mine, clay rests on St. Peter sandstone and possibly in other part on "Trenton" limestone	13	..
Outside the mouth of the mine lower beds are exposed as follows:		
6. Sandstone, thin layer	..	3
5. Clay, coal and coaly shale (No. 1 [?])	..	6
4. Fireclay, very fine textured, plastic, and light in color (Sample No. 96, p. 399)	4	..
3. Fireclay, sandy	2	..
2. Pyrite bed, less than	..	2
1. Limestone, Trenton	..	..

The clay is hauled by train and electric motor to the mill and after grinding is carried by cable train across the Big Vermilion River to the Rock Island Railroad.

At Lowell the clay below the No. 2 coal has been used in a small way for pottery at the Lowell Stoneware Company's plant.

Section of the Lowell Stoneware Company's pit at Lowell

	Thickness Feet
4. Overburden, drift and soil	1 to 12
3. Coal (No. 2)	3½
2. Clay (Sample No. 90, p. 400), dark gray to light drab "W" clay; the upper three feet contains much pyrite at the base of which there are locally traces of green coloring	12 to 25
1. Limestone, Trenton	..

Preliminary drilling is said to have proved that the clay underlies at least 200 acres. A great part of this is overlain by an overburden of less than 15 feet and could easily be removed by steam shovel.

Near the river bank small quantities of clay have been dug from directly beneath 1 to 7 feet of soil and drift overburden. The clay here is distinctly bedded and of a gray color with an occasional yellow pocket. It is sold as the "R" clay (sample No. 89, p. 400).

The Pennsylvanian rocks are missing on the east flank of the La Salle anticline at Utica. The bluffs of Illinois Valley are largely St. Peter sandstone from Utica to Twin Bluffs on the south side of Illinois River. At Twin Bluffs the National Fireproofing Company is working clay in open cut from directly above the St. Peter sandstone, and about a mile to the east the

Herrick Clay Manufacturing Company is tunneling the clay (sample No. 95, p. 401) from the same horizon. A section of the face of the former pit is given here:

Section of National Fireproofing Company's pit at Twin Bluffs

	Thickness Ft.	In.
5. Overburden, drift	unmeasured	
4. Shale ("Soapstone")	8	..
3. Coal (No. 2)	1	11
2 Shale, black	..	6
1. Clay (Sample No. 94, p. 402); lighter in color and more sandy toward the bottom	7	..

At the Herrick mine the clay is 8 feet thick and because of the eastward dip the overlying shale has increased to more than 30 feet. At the National Fireproofing pit the drift overburden and the shale are used for drain tile and building blocks. The coal above the clay is also recovered. At both plants the clays are ground and shipped. The output from the National Fireproofing plant is approximately 800 tons per week and a similar or somewhat lesser quantity is shipped from the Herrick mine.

At Ottawa the Fox and Illinois rivers have cut through the Pennsylvanian and are now flowing on St. Peter sandstone. About 2 miles east of that city basal Pennsylvanian clay is dug from two open pits; that of the Chicago Retort and Firebrick Company and that of the National Fireproofing Company.

Section of the National Fireproofing Company's "Pioneer" pit 2 miles east of Ottawa

	Thickness Ft.	In.
10. Soil	..	6
9. Shale ("soapstone")	16	..
8. Coal	2	2
7. Fireclay, dark	1	..
6. Fireclay, lighter gray (Sample No. 91, p. 403); lenses of large rounded pisolitic boulders which contain large amounts of pyrite	8	..
5. Clay, green, in lenses, local	..	2
4. Sandstone, hard, brown	1 to 4	..
3. Clay, very light in color (Sample No. 92, p. 404)	5 to 9	..
2. Clay, sandy	1	..
1. Sandstone, St. Peter	..	..

The clay is dug by steam shovel and hauled by electric tram to the plant at Ottawa. The output is about 5000 tons of manufactured ware per month, chiefly hollow ware and fire brick, and 1000 tons of ground fireclay.

Section of the Chicago Retort and Firebrick Company's pit northeast of Ottawa

	Thickness Ft.	In.
8. Soil	1	..
7. Shale, blue, weathers light; "soapstone"	17	..
6. Shale, darker; colored by carbon	2	..
5. Coal	2	..
4. Gypsum, persistent layer	..	1
3. Clay, colored by carbon	..	2
2. Fireclay (Sample No. 101, p. 404); traces of green in lower beds where clay becomes lighter in color; large rounded sandy pyritic boulders in bottom of pit; smaller pyrite concretions scattered in the clay	4 to 8	..
1. Sandstone, St. Peter	..	..

This section differs little from the preceding one, except that instead of the lower clay it has the green clay resting directly upon the St. Peter sandstone. A large area of this clay has been removed, but the Company reports holdings of 300 acres of tested reserve clay land east and north of the present pit. No use is made of the overburden which is removed by steam shovel and tram.

Three grades of clay are used: (1) Raw clay from this pit; (2) raw clay blended with Missouri flint clay; and (3) raw clay blended with a mixture of raw and calcined Missouri flint clay.

About half a mile southeast of Dayton, clay is mined from a tunnel driven in the side of a deep ravine.

Section at Dayton Clay Works half a mile south of Dayton

	Thickness Feet
6. Loam, drift, and soil	6
5. Shale, more compact toward the base	32
4. Shale, dark blue	1
3. Coal (No. 2)	2 ±
2. Clay, sandy, pyritic gray (Sample No. 99, p. 406)	4½ to 5½
1. Sandstone	..

Sample No. 102 (p. 406) was from an outcrop of the gray fireclay above.

The clay is ground and loaded by elevated conveyor onto a switch of the Chicago, Burlington and Quincy Railroad about 100 yards east of the plant.

The Chicago Firebrick Company is reopening the entries of the old Spicer Coal Company's mine 2 miles east of Marseilles with the intention of obtaining the clay which here is at a depth of about 90 feet. The clay is worked from a new face at the outer margin of the former mine by the room and pillar system.

Section of Chicago Firebrick Company's shaft 2 miles east of Marseilles

		Thickness *Feet*
	Shaft from top of coal to surface	90 ±
4.	Coal (No. 2)	2½
3.	Fireclay, drab, comparatively free from pyrite but colored by carbon	3½ to 6
2.	Clay, green; rich in pyrite	½ to 3
1.	Fireclay; pyrite in small crystals to bottom of present workings; a maximum of 12 feet of this lower clay has been penetrated; at the shaft the St. Peter sandstone is 8 feet 4 inches below the bottom of the coal	5

The clay is shipped as ground clay.

Sample No. 129 was taken from the working face omitting the green clay. (See page 408).

South and east from Utica, or away from the crest of the La Salle anticline, the base of the Pennsylvanian beds lowers and in only a few places have mine shafts penetrated to the level of the clay.

Two miles south of Streator, the shaft of the Streator Clay Manufacturing Company penetrates the No. 2 coal, but the underlying clay is not of as good a quality as that farther north.

Section of Streator Clay Manufacturing Company's shaft 2 miles south of Streator

		Thickness *Ft.*	*In.*
	Shaft	230	..
4.	Coal (No. 2)	2	6
3.	Fireclay, gray and blue (Sample No. 130-a, p. 408)	1⅓ to 4	..
2.	Clay, sandy, "sandrock"	3 to 5	..
1.	Clay, greenish gray; "Intermediate clay" (Sample No. 130-b, p. 408)	2	6
	Bottom not reached.		

At Kangley the Spring Lake Coal Company is mining the No. 2 coal. Clay brought out in lifts from digging sumps was sampled from the dump. Results of tests on the sample (No. 131) are given on page 408.

Section of the Spring Lake Coal Company's shaft at Kangley 4 miles northwest of Streator

		Thickness *Feet*
	Shaft	200
2.	Coal (No. 2)	3
1.	Clay (Sample No. 131); bluish and greenish gray with small gypsum crystals and an occasional iron stain	5
	Bottom not reached.	

RESULTS OF TESTS

LA SALLE COUNTY

Sample No. 87

(East pit of the Utica Firebrick and Clay Company;
2 miles south of Utica)

This clay is of medium hardness. It is of a dark gray or slate color speckled with a few black spots. The plasticity is very high when it is tempered with water, and its conduct when flowing through a die is good.

Water of plasticity	*per cent*	25.6
Shrinkage water	*per cent*	17.0
Pore water	*per cent*	8.6
Modulus of rupture	*lbs. per sq. in.*	497.6
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	290.3
Slaking test, average	*min.*	10.5

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	None	....
40	Trace	....
60	0.4	Fine white sand
80	0.2	Fine white sand
120	0.7	Fine white sand
200	0.9	Fine white sand

Drying shrinkage:—

	Per cent
Linear; dry length	9.3
Linear; wet length	8.5
Volume	34.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	17.0	Cream, nearly white	3.1	....
2	12.3	Light cream	4.2	Fine iron spot
4	10.7	White exterior	...	Fine iron spot
8	8.4	Cream	5.1	Numerous fine iron spots
9	8.2	Cream	5.1	Numerous fine iron spots
12	4.7	Bluestoned; cream	5.8	Numerous fine iron spots
14	5.0	Dark buff; bluestoned	5.6	Numerous fine iron spots, slagged

Oxidation conduct:—Appears to be very slow.

Fusion test:—Deforms at cone 28.

Summary

The strength of the raw clay is medium high and its bonding strength is high. The amount of residue on the sieves is slight. The drying shrinkage is medium and the total shrinkage at cone 9 is medium high. Vitrification is incomplete at cone 14. Oxidation appears to have been very slow. It is a refractory clay.

Suggested uses: Stoneware, architectural terra cotta, sanitary ware, face brick, refractories.

Sample No. 77

(East pit of the Utica Firebrick and Clay Company; 2 miles south of Utica)

This is a very hard dark gray colored clay. When powdered and tempered with water, it develops a fair degree of plasticity and will flow through a die satisfactorily.

Water of plasticity	*per cent*	19.8
Shrinkage water	*per cent*	9.3
Pore water	*per cent*	10.5
Modulus of rupture	*lbs. per sq. in.*	320
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	261
Slaking tests, average	*min.*	9

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	0.1	Quartz and pyrite
40	0.2	
60	1.0	
120	1.8	
200	1.2	

Drying shrinkage:—

	Per cent
Linear; dry length	7.5
Linear; wet length	7.0
Volume	19.2

Drying conduct:—Efflorescence, i. e., "whitewash," appears at the corners of the sample.

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	14.4	Cream	4.4	Granular fracture
3	11.0	Cream	4.8	Granular fracture
6	8.5	Darker cream	5.4	Granular fracture
8	5.1	Grayish	5.5	Granular fracture
9	4.4	Grayish	5.1	....
12	6.0	Bluestoned	4.3	....
12½	...	Tan, light bluestoned	...	....
15	5.0	Buff exterior; bluestoned, black	3.6	Some iron spots

Fusion test:—Cone ⅓ deformed at cone 28. Vesicular structure.

Summary

The clay has a medium strength and a medium bonding strength. The drying shrinkage is medium and at cone 9 the total shrinkage is medium high. The clay attains a fairly low degree of porosity at cone 6 and is not overburned at cone 15. It is a refractory clay.

Suggested uses: Stoneware, architectural terra cotta, sanitary ware, refractories, face brick.

Sample No. C82

(West pit of the Utica Firebrick and Clay Company, near Utica)

This sample was a mixture of a light colored material, which was very hard, and a soft yellow mass. When tempered with water it developed a very good plasticity and could be squeezed through a die satisfactorily.

Water of plasticity	per cent	32
Shrinkage water	per cent	16.9
Pore water	per cent	15.1
Modulus of rupture	lbs. per sq. in.	484.8
With 50% standard sand—Modulus of rupture	lbs. per sq. in.	185.2
Slaking test, average	min.	9

Screen test:—

Mesh	Residue *Per cent*	Character of residue
10	7.8	Sand, colored rock fragments
14	3.5	Sand, colored rock fragments
20	3.5	Sand, colored rock fragments
35	1.3	Sand, colored rock fragments, and coal
48	Trace	Sand, colored rock fragments, and coal
65	1.0	Sand, colored rock fragments, and coal
100	Trace	......
150	Trace	......
200	Trace	......

Drying shrinkage:—

	Per cent
Linear	6.8

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
02	33.7	Reddish cream	1.8	......
1	3.9	Dark gray	12.7	Very brittle
3	2.2	Dark gray	13.6	Very brittle
5	1.0	Dark brown	12.5	Bloated. Sample heated above this cone was melted.

Fusion test:—Complete fusion at cone 26. Cone shows vesicular structure, but not very decided.

Summary

The strength of the clay is medium high. Its bonding strength is medium low. The drying shrinkage is medium. Total shrinkage at cone 5 is medium high. It appears bloated as though overburned at cone 5. The clay is non-refractory.

Suggested uses: Common brick and tile.

Sample No. 97

(M. J. Gorman and Company's pit; 1½ miles south of Utica)

The following tests relate to the sample collected by Mr. Culver.

The material is of a medium hard shaly nature. With it is mixed a softer portion. The color is dark gray and brown. A good plasticity may be developed. When forced through a die, the clay flows rather badly.

Water of plasticity	per cent	35.6
Shrinkage water	per cent	22.9
Pore water	per cent	12.5
Modulus of rupture	lbs. per sq. in.	565
With 50% standard sand—Modulus of rupture	lbs. per sq. in.	201
Slaking test, average	min.	60

Screen test:—

Mesh	Residue Per cent
20	0.3
40	17.3
60	17.6
80	6.0
120	0.8
150	1.8
200	4.0

Drying shrinkage:—

	Per cent
Linear; dry length	10.5
Linear: wet length	9

Drying conduct:—Shows tendency to warp.

Burning test:—

Cone	Porosity Per cent	Color	Burning shrinkage Per cent
08	30	Salmon	1.6
06	27	Buff	2.2
04	24	Cream	3.1
02	23	Buff	4.0
1	22	Buff	4.6
2	16	Stoneware	5.4
4	9.5	Gray	5.7
7	5.6	Gray	5.2
9	6.5	Gray	5.5
10	4.4	Gray with brown specks	5.3

Fusion test:—It fused at cone 28.

Summary

The strength of the clay is medium high. Its bonding strength is medium. The total percentage of residue on the screens is high. The drying shrinkage is medium high at cone 9. The total shrinkage is high. The vitrification proceeds slowly and is incomplete at cone 10. It is a refractory clay.

Suggested uses: Refractories, face brick.

Sample No. 100

(M. J. Gorman and Company's pit; 1½ miles south of Utica)

Resampled by Mr. Culver.

The clay is a very hard gray colored material. Its conduct when forced through a die is good.

Water of plasticity	*per cent*	24.6
Shrinkage water	*per cent*	13.8
Pore water	*per cent*	10.8
Modulus of rupture	*lbs. per sq. in.*	475
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	222
Slaking test, resample	*min.*	40

Screen test:—

Mesh	Residue Per cent	Character of residue
20	0.2	Fragments of rock and pyrites
40	0.06	Sand and pyrites
60	3.5	Sand, particles of clay and pyrites
80	2.1	....
120	14.1	Particles of clay
150	3.4	Particles of clay
200	6.5	Particles of clay

The sample did not slake completely.

Drying shrinkage:—Linear; wet length....*per cent* 7.3

Burning test:—

Cone	Porosity Per cent	Color	Burning shrinkage Per cent
08	24	Light gray	2.1
06	23	Buff and cream	2.5
04	20	Dark cream	3.3
02	18	Dark cream	4.0
1	16	Dark cream	4.4
3	12	Gray	5.0
5	8	Gray with iron speckles	5.5
7	6	....	5.5
9	6	....	5.5
11	7	Brown	5.7

Fusion test:—It deformed at cone 31.

Summary

The strength of the clay is medium high. Its bonding strength is medium. The amount of screen residues is high. The drying shrinkage is medium. The total shrinkage at cone 9 is medium high. Vitrification is incomplete at cone 11. It is a refractory clay.

Suggested uses: Refractories, face brick. The slow slaking properties may limit its usefulness for terra cotta, stoneware, and sanitary ware.

Sample No. 98

(Side of gully near M. J. Gorman and Company's pit, near Utica)

This report relates to sample obtained by Mr. Culver.

This is a soft clay, yellow in color and marked with brown spots. When tempered with water, it has good plasticity.

Water of plasticity ....*per cent* 28
Shrinkage water ....*per cent* 12.7
Pore water ....*per cent* 15.3
Modulus of rupture ....*lbs. per sq. in.* 246
With 50% standard sand—Modulus of rupture ....*lbs. per sq. in.* 149
Slaking test, average ....*min.* 65

Screen test:—

Mesh	Residue Per cent	Character of residue
20	4.2	Chert and sandstone fragments
40	1.0	....
60	2.8	....
80	5.3	White and yellow sand
120	2.2	White and yellow sand with some mica
150	2.00	White and yellow sand with some mica
200	4.8	White and yellow sand with some mica

Drying shrinkage:—Linear; wet length .... *per cent* 6.2

Burning test:—

Cone	Porosity Per cent	Color	Burning shrinkage Per cent
08	36	Brownish red	1.7
06	34	Brownish red	2.2
04	32	Brownish red	3.4
02	31	Brownish red	3.8
1	30	Brownish red	4.3
3	28	Chocolate	5.0
5	22	Bluish black	6.2
7	19	Bluish black	6.8
9	17	Bluish black	7.6

Fusion test:—It deforms at cone 29.

Summary

The clay has a medium strength, a medium low bonding strength, and a medium drying shrinkage. It contains a considerable percentage residue material too coarse to pass the screen test. The total shrinkage at cone 9 is medium high. The clay is quite open burning. The very dark color of the samples carried to cone 5 and beyond suggests the possibility of reduction during burning. It is refractory.

Suggested uses: Face brick. The dark color of the burned clay and its burning conduct suggest the possibility of the iron content being abnormally high for a refractory material, even though the fusion test was satisfactory.

Sample No. 93

(Illinois Clay Products Company's mine at Deer Park)

This is a dark gray colored clay which is a semi-flint in its character. It appears to contain a notable amount of pyrites.

Water of plasticity .... *per cent* 25
Shrinkage water .... *per cent* 15.9
Pore water .... *per cent* 9.1
Modulus of rupture .... *lbs. per sq. in.* 554.7
With 50% standard sand—Modulus of rupture .... *lbs. per sq. in.* 302.5
Slaking test, average .... *min.* 10½

Drying shrinkage:—

	Per cent
Linear; wet length	7.2
Linear; dry length	7.8
Volume	32.6

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	7.2	Grayish white	6.0	Nearly vitreous
3	3.3	Gray	6.3	Nearly vitreous fracture
6	3.0	Gray	6.6	Nearly vitreous
8	2.2	Gray	5.5	Some fine iron spots
12	11.8?	Bluestoned	2.6	....
13	7.3	Buff; slagged spots; blue core.	3.2	Buff exterior, blue core, numerous iron spots
15	4.6	Dark terra cotta flash outside; gray inside	4.0	.... Large iron spots overburned

Fusion test:—It deformed at cone 29.

Summary

The strength of the clay is medium high and its bonding strength is medium. The drying shrinkage is medium. The total shrinkage at cone 8 is medium high. It is practically non-porous at cone 8 and is slightly overburned at cone 13. It is a refractory clay.

Suggested uses: Refractories, especially those requiring a clay having a good strength and burning to a dense structure. Facebrick. Its slow slaking property when mixed with water is rather unfavorable for its use for stoneware and terra cotta.

Sample No. 96

(Illinois Clay Products Company's mine at Deer Park)

The sample was a hard, dark gray colored material of medium plasticity.

Water of plasticity	*per cent*	19
Shrinkage water	*per cent*	10
Pore water	*per cent*	9
Modulus of rupture	*lbs. per sq. in.*	277
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	107.3
Slaking test, average	*min.*	7

Screen test:—Too hard to slake.

Drying shrinkage:—

	Per cent
Linear; dry length	5.8
Linear; wet length	5.5
Volume	20.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	18	White	3.9	....
2	17	Light cream	4.4	Earthy fracture
3	14	Light cream	...	....
6	12	Light cream	6	Earthy fracture
9	7	Cream	6.1	Granular
12	3.0	Bluestoned; uniform gray	7	Earthy fracture
13	2.4	Bluestoned; uniform gray	6.8	Earthy fracture
15	2.4	Bluestoned; uniform gray	7.0	....

Fusion test:—It fused about cone 31.

Summary

The strength of the clay is medium and its bonding strength is medium low. The drying shrinkage is medium. At cone 9 the total shrinkage is medium. Vitrification is nearly complete at cone 12 and there is no sign of overburning at cone 15. It is refractory.

Suggested uses: Refractories and face brick. Its slow slaking is rather unsatisfactory for stoneware and architectural terra cotta.

Sample No. 90

(Lowell Stoneware Company's pit; at Lowell)

This is a hard dark colored, i. e., gray clay which becomes very plastic when tempered with water. Its conduct when flowing through a die is very good.

Water of plasticity	*per cent*	20.8
Shrinkage water	*per cent*	8.5
Pore water	*per cent*	12.2
Modulus of rupture	*lbs. per sq. in.*	420
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	290
Slaking test, average	*min.*	9

Screen test:—Clay was too hard to slake.

Drying shrinkage:—

	Per cent
Linear; dry length	6.8
Linear; wet length	6.2

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	18	White	4.1	
3	14	Light cream	5.0	Earthy fracture
6	12	Light cream	5.6	Earthy fracture
9	9.5	Cream	5.7	
12	5.0	Darker cream	7.0	Granular but vitreous fracture
15	2.0	Tan exterior; bluestoned badly.	7.6	

Fusion test:—Deformation at cone 30/31.

Summary

The strength of the clay is medium high and its bonding strength is medium. Because of its hardness, the clay could not be slaked properly for the screen tests. The drying shrinkage is medium. The total shrinkage at cone 9 is medium. Vitrification is practically complete at cone 15. It is a refractory clay.

Suggested uses: Refractories, especially if good bonding power is desired. Its slow slaking property is a disadvantage for stoneware and architectural terra cotta, although otherwise it seems adapted to these uses.

Sample No. 89

(Near river bank at Lowell)

This report relates to a resampling of the deposit by Mr. Culver. This hard clay is of a gray color and it has a low degree of plasticity. The conduct of the plastic body when forced through a die is only fair.

Water of plasticity	*per cent*	18
Shrinkage water	*per cent*	6.6
Pore water	*per cent*	11.3
Modulus of rupture	*lbs. per sq. in.*	179
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	137.6
Slaking test, average	*min.*	12

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	4.5	Particles of coal, rock and pyrites
40	6.8	Particles of coal, rock and pyrites
60	2.3	Particles of coal, rock and pyrites, some mica
80	1.1	Particles of clay
120	0.9	Particles of clay
150	2.0	Particles of clay
200	9.4	Particles of clay

Drying shrinkage:—Linear .... *per cent* 4.3

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
08	30	White	+.4	....
06	27	Cream	+0.3	....
04	28	Cream	−0.1	....
02	28	Cream	0.26	....
1	27	Cream	0.3	....
3	25	Cream	1.0	....
5	19	Cream with black spots	2.5	....
7	19	Cream with black specks	2.2	....
9	17	Black specks	2.0	....
11	12	Black specks	2.5	Appears overburned

Fusion test:—Fused completely at cone 26.

Summary

The strength of the unburned clay is medium low. Its bonding strength is medium low. The amount of residues on the sieves is high. The total shrinkage at cone 9 is medium low. The vitrification is still quite incomplete at cone 11, although it has the appearance of having been overburned. It is a non-refractory clay.

Suggested uses: Stoneware, although the hardness and slow-slaking properties together with the low strength may be quite disadvantageous; face-brick.

Sample No. 95

(Herrick Clay Manufacturing Company; 1 mile east of Twin Bluffs)

This sample appears to be a mixture of clay and quartzite lumps and grains. It is a grayish or dark color.

Modulus of rupture	*lbs. per sq. in.*	157
Slaking test, average	*min.*	6

Screen test:—

Mesh	Residue Per cent	Character of residue
20	3.5	Quartz sand and pyrites
40	1.8	
60	13.9	
120	23.3	
200	2.6	

Fusion test:—Deforms at cone 27.

Summary

The strength test is medium low. The percentage of residues on the screens is high. It is refractory.

Sample No. 94

(National Fireproofing Company's pit at Twin Bluffs)

The sample is a dark gray, hard clay which contains some sandy material. When tempered with water a medium degree of plasticity may be developed. It does not flow readily through the die.

Water of plasticity	*per cent*	16.9
Shrinkage water	*per cent*	7.6
Pore water	*per cent*	9.2
Modulus of rupture	*lbs. per sq. in.*	140.6
Slaking test, average	*min.*	8½

Screen test:—Sample does not slake.

Drying shrinkage:—

	Per cent
Linear: dry length	4.0
Linear; wet length	3.9
Volume	15.9

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	24.7	Gray	...	Specked with iron
1	25.3	Grayish white	1.0	
3	24.6	Cream	1.5	
5	21.9	Light brown	...	
7	22.1	Light brown	2.0	
9	22	Dark brown	2.0	
12	19	Terra cotta	2.0	Color may be due to flashing
13	16	Red brown with black spots on interior	3.0	....
15	11	Bluestoned, gray black	5.0	....

Oxidation conduct:—Material seems to flash very readily.

Fusion test:—It deforms at cone 31.

Summary

The strength of the clay is medium low. Its drying shrinkage is medium low. At cone 9 the total shrinkage is medium low. The clay is quite open burning, vitri-

fication being incomplete at cone 15. It is a refractory clay.

Suggested uses: The rather poor plasticity may render it difficult to form this clay readily; otherwise it is adapted to use for face brick. Although the fusion test indicates a material of refractory nature, yet the presence of numerous iron spots as indicated at the lower cones is not very satisfactory.

Sample No. 91

(National Fireproofing Company's pit; 2 miles east of Ottawa)

This is a hard clay of a dark gray color which contains a notable amount of pyrites. It is fairly plastic.

Water of plasticity	*per cent*	17.3
Shrinkage water	*per cent*	9.1
Pore water	*per cent*	8.2
Modulus of rupture	*lbs. per sq. in.*	309.5
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	236.7
Slaking test, average	*min.*	9

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	Trace	....
40	0.3	Pyrite and sand
60	2.3	
80	1.1	
120	2.1	
200	2.4	

Drying shrinkage:—

	Per cent
Linear; dry length	6.8
Linear; wet length	6.3
Volume	18.9

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
04	24.8	White	2.6	Fine specks of iron oxide
02	22.4	White	3.5	Fine specks of iron oxide
2	18.5	Grayish white	4.8	Granular
5	16.5	Grayish white	5.4	Granular
9	14.0	Grayish white	5.6	Numerous fine iron spots
13	7.9	Grayish white	7.0	....
14	6.3	Brown red; bluestoned	5.3	Iron spots, slagged
15	16.3	Brown red; bluestoned	4.8	Iron spots, slagged

Fusion test:—Fused completely at cone 27.

Summary

The strength of the clay is medium and its bonding strength is medium. The percentage of residues left on the sieves is moderate. The drying shrinkage is medium and the total shrinkage at cone 9 is medium. Vitrification is incomplete at cone 14 and apparently the clay is overburned at cone 15. It is non-refractory.

Suggested uses: Stoneware, architectural terra cotta and sanitary ware (the presence of pyrites may make this use impossible), face brick.

Sample No. 92

(National Fireproofing Company's pit; 2 miles east of Ottawa)

This is a very hard clay of a light gray color. It has only a medium plasticity. It flows readily through a die.

Water of plasticity .... *per cent* 17
Shrinkage water .... *per cent* 6.9
Pore water .... *per cent* 10.1
Modulus of rupture .... *lbs. per sq. in.* 201
Slaking test, average .... *min.* 5

Drying shrinkage:—

	Per cent
Linear; dry length	4.7
Volume	14

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
01	17.8	White	4.7	....
2	17	Light cream	4.9	Earthy fracture
3	13	Light cream	6.0	Earthy fracture
6	12	Light cream	6.4	Earthy fracture
9	8	Light cream	6.2	Earthy fracture
12	4.7	Darker light buff	6.9	Very fine iron spots evenly distributed
15	6.1	Light buff; bluestoned	7.1	....

Fusion test:—It deformed at cone 29.

Summary

The strength of the clay is medium. Its drying shrinkage is medium low. The total shrinkage at cone 9 is medium. It still has an appreciable porosity at cone 12 and apparently is slightly overburned at cone 15. It is a refractory clay.

Suggested uses: Refractories, stoneware, architectural terra cotta.

Sample No. 101

(Chicago Retort and Firebrick Company's pit, northeast of Ottawa)

This is a dark gray colored, very hard clay, which develops a fair plasticity when tempered with water. It flows only fairly well through a die.

Water of plasticity .... *per cent* 20.0
Shrinkage water .... *per cent* 11.5
Pore water .... *per cent* 8.5
Modulus of rupture, maximum .... *lbs. per sq. in.* 532
Modulus of rupture, average .... *lbs. per sq. in.* 335
With 50% standard sand—Modulus of rupture:—14 of 20 pieces gave an average (not including values of 292.5 and 296.0) .... *lbs. per sq. in.* 177
Slaking test, average .... *min.* 7½

Drying shrinkage:—

	Per cent
Linear; dry length	7.0
Linear; wet length	6.5
Volume	23.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	19	Cream	3.6	....
2	17	Cream	4.0	Earthy fracture
4	..	Cream	4.4	Earthy fracture
6	15	Darker cream	4.2	Earthy fracture
9	13	Cream	4.4	Earthy fracture
12	11	Light terra cotta; flashed	4.1	Many fine iron spots
13	12	Light terra cotta; flashed	4.6	Many fine iron spots, slagged
15	13	Buff	5.3	Golden buff, numerous iron spots

Fusion test:—It deforms at cone 29.

Summary

The tests of the clay showed it to have medium strength, but it should be noted that a single test piece gave a much higher value. The bonding test also gave two values, considerably higher than the average of a large number of pieces. The drying shrinkage is medium. The total shrinkage at cone 9 is medium. Vitrification is incomplete at cone 12, at which temperature it is still quite open. Apparently slight overburning occurs above this point. The clay is refractory.

Suggested uses: Face brick, stoneware, architectural terra cotta, sanitary ware, refractories.

Sample No. 99

(Dayton Clay Works; ½ mile south of Dayton)

The clay is of a dark gray color. It is quite sandy (see screen test), and the plasticity is low. It flows poorly through a die.

Water of plasticity	*per cent*	15.9
Shrinkage water	*per cent*	5.1
Pore water	*per cent*	10.8
Modulus of rupture	*lbs. per sq. in.*	215
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	107
Slaking test, resample	*min.*	22½

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	4.9	Pyrites and carbonaceous matter
40	0.3	Pyrites and quartz sand
60	5.8	White quartz sand
80	3.7	Quartz sand
120	8.4	Quartz sand
200	4.5	Darker colored sand

Drying shrinkage:—

	Per cent
Linear; dry length	4.9
Linear; wet length	4.7
Volume	9

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
08	30	Light gray white	2.0	
06	30	Light gray white	2.0	
04	30	Light gray white	2.0	
02	29	Light gray white	4.1	
1	25	Light gray white	6.2	
3	22	Light gray white	9.3	
5	..	Light gray white; iron specks	8.3	
6	23	Slightly darker	...	
7	..	Slightly darker	6.2	
9	19	Slightly darker	...	
12	16	Terra cotta; flashed	...	Numerous iron spots
15	21	Terra cotta; flashed	...	Many large iron spots

Fusion test:—It fused at cone 30.

Summary

The clay has a medium strength, and a medium low bonding strength. The amount of screen residues is high. The drying shrinkage is medium low. The minimum porosity was reached at cone 12 and it appeared to overburn at cone 15. The fusion test indicates a refractory clay.

Suggested uses: Face brick. Certain types of refractories.

Sample No. 102

(Resampled by H. E. Culver)

(Dayton Clay Works; ½ mile south of Dayton)

This is a hard clay which is dark gray, nearly black in color. When tempered with water, it becomes very plastic and flows through a die satisfactorily.

Water of plasticity .... *per cent* 33
Shrinkage water .... *per cent* 12
Pore water .... *per cent* 21
Modulus of rupture .... *lbs. per sq. in.* 297
With 50% standard sand—Modulus of rupture .... *lbs. per sq. in.* 223
Slaking test, average .... *min.* 13

Screen test:—

Mesh (Sample slaked badly.)	Residue *Per cent*	Character of residue
20	0.8	Sand
40	0.3	
60	1.9	Clay particles
80	0.4	Clay particles
120	1.0	Clay particles
150	0.6	Clay particles
200	0.9	Clay particles

Drying shrinkage:—Linear; wet length .... *per cent* 6.0

Burning test:—

Cone	Porosity	Color	Burning shrinkage
	Per cent		*Per cent*
08	29	Salmon	3.0
06	23	Brownish red	4.4
04	15	Darker	6.3
02	12	Chocolate	7.6
1	7	Gray	9.2
3	1.2	Greenish black	9.4
5	Overburned		

Fusion test:—Completely fused at cone 27. Vesicular.

Summary

The clay has a medium strength and a medium bonding strength. It slakes rather poorly and leaves a moderate amount of residues upon the screens. The drying shrinkage is medium. The clay has a short heat range. It reaches a minimum porosity at cone 3 and is overburned at cone 5. It is non-refractory.

Suggested uses: Brick and tile.

Sample No. 129

(Resampled by Mr. Culver)

(Chicago Firebrick Company's shaft; 2 miles east of Marseilles)

This clay has a dark gray color. It is very hard. When tempered with water, it has good plasticity. Its conduct when squeezed through a die is fair.

Water of plasticity	*per cent*	32.9
Shrinkage water	*per cent*	21.7
Pore water	*per cent*	11.2
Modulus of rupture, maximum	*lbs. per sq. in.*	900
Modulus of rupture, average	*lbs. per sq. in.*	795
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	247
Slaking test, 2nd sample	*min.*	34

Screen test:—

Mesh	Residue	Character of residue
	Per cent	
20	1.2	Quartz, coal, pyrites
40	0.4	....
60	0.8	....
80	1.3	Particles of hard clay
120	0.4	Particles of hard clay
150	0.3	Particles of hard clay
200	1.27	Particles of hard clay

Drying shrinkage:—

	Per cent
Linear; dry length	12.5
Linear; wet length	10.0

Burning test:—

Cone	Porosity	Color	Burning shrinkage
	Per cent		*Per cent*
08	22	Cream	1.5
06	20	Cream	2.1
04	13	Grayish	3.0
02	12	Grayish	4.0
1	7	Grayish	4.2
3	8	Grayish	4.4
4	Overburned	Iron spots	...

Fusion test:—It deforms at cone 27/28.

Summary

The strength of this clay as determined by taking the average of nineteen of twenty-one test pieces is medium high. It should be noted that the maximum strength test of 900 pounds per square inch was obtained with four test pieces. The bonding test was medium. The amount of residues left upon the screens was moderate. The drying shrinkage was medium high and the total shrinkage at cone 1 was high. The sample appeared to be overburned at cone 4. The fusion test indicates a refractory clay.

Sample No. 130-a

(Streator Clay Manufacturing Company's shaft; 2 miles south of Streator)

This is a dark colored, very hard clay, which contains much pyrite. Its slaking time averages 6½ minutes. It is completely fused at cone 25.

Sample No. 130-b

(Streator Clay Manufacturing Company's shaft; 2 miles south of Streator)

This is a dark colored, i. e., grayish, very hard clay. The average time of the slaking test was nineteen minutes. It is completely fused at cone 25.

Sample No. 131

(Spring Lake Coal Company's shaft at Kangley)

This is a hard, greenish-gray colored clay, which is stained with iron oxide. It has a conchoidal fracture. When tempered with water, a medium plasticity may be developed. Its conduct when forced through a die is satisfactory. The occurrence of gypsum crystals in the clay was noted.

Water of plasticity	*per cent*	29.7
Shrinkage water	*per cent*	13.3
Pore water	*per cent*	16.4
Modulus of rupture	*lbs. per sq. in.*	361.8
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	192.6
Slaking test, average	*min.*	15

Drying shrinkage:—

	Per cent
Linear	5.7
Volume	20.0

Screen test:—

Mesh	Residue Per cent	Character of residue
10	0.9	Particles of shale, pyrite, and coal
14	1.0	
20	1.1	
35	2.6	
48	1.18	
65	1.0	
100	0.8	
150	0.65	
200	0.50	

Burning test:—

Cone	Porosity Per cent	Color	Total shrinkage Per cent	Remarks
04	10.3	Terra cotta	13.9	Scummed by efflorescent salts
01	1.75	Terra cotta	15.3	Vitreous glassy fracture
3	0.9	Reddish brown	15.3	Vitreous glassy fracture
5	4.8	Brown	....	Overburned, bloated
7	11.8	Brown	....	Overburned, bloated

Soluble salts:—Salts appear on the pieces after burning.
Fusion test:—It fused at cone 25.

Summary

The strength of the clay is medium. Its bonding strength is medium low. The amount of coarse particles is moderate and the fractions are quite evenly distributed. The total shrinkage at cone 3 is high. The clay vitrifies rapidly at a low temperature and is overburned at cone 5, thus having a very limited heat range. It is non-refractory.

Suggested uses: Common brick.

GRUNDY COUNTY

An exceptional thickness of clay is found in the depression formerly occupied by Goose Lake. Lenses of this clay are of a semi-flinty nature and thin layers of coal are interbedded with it. This coal varies in thickness, and at the west end will total 6 or 7 feet. The total thickness of the clay is reported to vary from 30 to 40 feet and the overburden over the 200 acre deposit ranges from practically nothing to 6 or 8 feet with an average of about 3 feet. A drilling 30 feet deep did not reach the bottom of the clay. "Islands" of rock are found in the clay and suggest its accumulation in solution basins in the crystalline Richmond limestone which outcrops at the north; at least these basins were in some way partly separated from the main "Coal Measures" sea at the south. Fig. 56 is a view of the clay pit at the west end of the Goose Lake area.

A face exposed in the bank of a small test pit is as follows:

FIG. 56. View of the clay pit at the west end of the Goose Lake area in Grundy County.

Section of upper part of Goose Lake clay

	Thickness *Ft.*	*In.*
5. Peaty soil and peat	..	8 to 10
4. Sandstone, local thin lenses	..	0 to 3
3. Fireclay, flint or semi-flint, drab, stained by iron and showing colorings of carbon (Sample No. 133)	1	..
2. Shale, stained black by carbon	..	6
1. Clay, drab gray with yellow stains of iron oxide (Sample No. 134)	3	6

The upper "flint" or "semi-flint" is underlain by a thin coal which is in turn above a plastic clay of lower refractory value.

An additional sample, known as No. X, which was obtained from a pit on the Anderson farm in Goose Lake Township, Grundy County, was collected and shipped to the Survey by D. C. Haeger. It is known as No. 1 fire clay, according to Mr. Haeger. The clay lies in a bed 5 feet in thickness and is covered by 20 to 24 feet of soft stone, 30 to 36 feet of sandstone, and 16 inches of black soil.

Results of tests on sample No. X are given on page 412.

RESULTS OF TESTS

GRUNDY COUNTY

Sample No. 133

(Clay pit at the west end of the Goose Lake area)

This is a drab colored, flinty clay, stained with iron. When ground and tempered with water, it develops a medium plasticity.

Water of plasticity	per cent	18.2
Shrinkage water	per cent	8.6
Pore water	per cent	9.6
With 50% standard sand—Modulus of rupture	lbs. per sq. in.	59.6
Slaking test, average	min.	3

Screen test:—

Mesh	Residue *Per cent*	Character of residue
40	0.14	Particles of hard clay and sand
60	0.24	
80	0.30	
120	0.64	
200	0.25	

Drying shrinkage:—

	Per cent
Linear; dry length	3.6
Linear; wet length	3.5
Volume	16.6

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	24	White	2.8	Earthy fracture
01	24.3	White	3.3	
3	22	White	4.2	
6	21	White	4.3	
9	17	Cream white	5.0	
12	12	Cream white	6.4	
13	8	Cream white	7.2	Granular fracture; numerous flinty particles and fine iron stain
15	6	Buff; lightly bluestoned	8.3	

Fusion test:—Deforms between cones 30 and 31.

Summary

The bonding strength of the clay is low. The drying shrinkage is medium low. The total shrinkage at cone 9 is medium. It has a low porosity at cone 15. It is a refractory clay.

Suggested uses: Refractories.

Sample No. 134

(Clay pit at west end of Goose Lake area)

This is a clay of medium hardness, and gray colored but stained with yellow. Tempered with water, it has a medium degree of plasticity and shows a tendency to laminate when forced through a die.

Water of plasticity	per cent	31.8
Shrinkage water	per cent	18.5
Pore water	per cent	13.3
Modulus of rupture	lbs. per sq. in.	442
With 50% standard sand—Modulus of rupture	lbs. per sq. in.	194
Slaking test, average	min.	14

Screen test:—

Mesh	Residue Per cent	Character of residue
20	0.1	Sand
60	0.7	Sand
80	0.1	Sand
120	0.9	Sand
200	0.3	Sand

Drying shrinkage:—

	Per cent
Linear; dry length	7.6
Linear; wet length	7.1

Burning test:—

Cone	Porosity Per cent	Color	Burning shrinkage Per cent	Remarks
04	30	Cream white	1.4	Earthy fracture
02	26	Cream white	3.0	
2	17	Cream white	5.4	
5	15	Cream white	6.0	
9	11	Cream white	6.7	
13	4.1	Light gray	7.2	Vitreous; not glassy
14	4.0	.....	6.4	.....
15	4.3	Light brown exterior; bluestoned or light gray	6.3	.....

Fusion test:—Deforms at cone 28.

Summary

The clay has a medium high strength and a medium low bonding strength. The drying shrinkage is medium. The amount of screen residues is low. At cone 9 the total shrinkage is medium high. It reaches a low degree of porosity at cone 13 and shows no sign of overburning at cone 15. It is a refractory clay.

Suggested uses: Refractories, architectural terra cotta, stoneware, sanitary ware, face brick.

Sample No. X

(Anderson farm in Goose Lake township)

This is a drab colored, flinty clay, which develops a medium plasticity when tempered with water—i. e., it is rather sandy or grainy. The plastic mass laminates badly when squeezed through a die.

Water of plasticity	*per cent*	26.6
Shrinkage water	*per cent*	14.6
Pore water	*per cent*	12.0
Modulus of rupture	*lbs. per sq. in.*	317.4
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	202.3

Screen test:—

Mesh	Residue Per cent	Character of residue
10	2.9	Fragments of coal and shale
14	1.8	
20	2.8	
35	8.5	
48	5.5	
65	5.4	

100	3.9	Fragments of coal and shale, and some mica
150	2.7	
200	3.0	

Drying shrinkage:—

	Per cent
Linear	6.2
Volume	26

Burning test:—

Cone	Porosity	Color	Hardness	Total shrinkage	Remarks
	Per cent			*Per cent*	
04	10.0	Gray	Very hard	12	Granular fracture
01	6.9	Gray	Very hard	13	....
1	12.5	Gray	Very hard	12	....
3	6.8	Gray	Very hard	12.7	....
5	2.4	Gray	Very hard	12.9	Slightly bluestoned
7	1.3	Gray	Very hard	12.9	....
9	0.4	Gray	Very hard	12.9	....
12	0.5	Gray	Very hard	13.1	....
14	0.5	Gray	Very hard	12.2	Some iron specks

Fusion test:—It deforms at cone 28.

Summary

The clay has a medium strength and bonding strength. The air shrinkage and total shrinkage are medium. It is almost completely vitrified at cone 5 and shows no signs of overburning throughout the firing range. It is refractory.

Suggested uses: Refractories, particularly those of a close texture.

JOHNSON COUNTY

About two miles southeast of Ozark station is a deposit of Pottsville oil shale or cannel coal which has been investigated by the Survey. Perhaps the best typical exposure of this deposit and the associated strata is that on the Stone land, a section of which is here given:

Section of oil shale measured in a test pit on the Frank Stone land in the NW. ¼ NW. ¼ sec. 35, T. 11 S., R. 4 E.

	Thickness Ft.	In.
8. Soil, yellow	1 to 5	..
7. Shale, chocolate, siliceous	4	2
6. Mud, red, merely a streak	..	..
5. Oil shale	2	9
4. Coal, bituminous	..	1½
3. Coal, cannel	..	4
2. Coal, bituminous, with peacock-colored blotches	..	2
1. "Fire clay," white	5+	..

In connection with the sampling of the oil shale a sample of the underlying clay was taken and tested with the results that follow.

Sample No. C-18—1

(Sample taken from below the cannel coal near Ozark in sec. 35, T. 11 S., R. 4 E.)

This sample is medium hard, gray colored clay, mottled with brown, which latter color may be due to the presence of organic matter. It has rather poor plasticity.

Water of plasticity	*per cent*	22.09
Shrinkage water	*per cent*	9.20
Pore water	*per cent*	12.89
Modulus of rupture	*lbs. per sq. in.*	147.3
Slaking test, average	*min.*	8
Drying shrinkage, linear	*per cent*	4.4

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
04	18.7	Light tan	8.3	Earthy fracture
01	16.4	Light tan	7.3	Earthy fracture
1	17.9	Gray	9	Earthy fracture
5	9.4	Dark gray	11.5	Earthy fracture
7	3.1	Dark gray	7	Shows signs of over-burning

Fusion test:—It fuses at cone 16.

Summary

The clay has a medium low strength and a medium drying shrinkage. The burning shrinkage at cone 5 is medium high. It seems to be overburned at cone 7. The trial pieces have the appearance of having been subjected to reducing conditions at and above cone 5. The clay is non-refractory, in fact, it is very fusible.

Suggested uses: Brick.

Tabulation of Certain Physical Tests

A knowledge of certain of the physical tests of a clay will enable the experienced person to determine very quickly whether it is likely to be of value for a specific purpose. Accordingly there are grouped in the following paragraphs classifications of the clays examined according to the results obtained in the more significant tests. A full explanation of the methods of testing and the interpretation has been given elsewhere.

Slaking test:—The samples which required more than thirty minutes for slaking according to the standard test were: Nos. 22, 38, 44 (169) 55, 58. 59, 60, 97, 98, 100, 129, 136.

Fusion test:—The samples which fused below cone 27 were: Nos. 17, 37-a, 41, 42, 47, 50, 52, 54, 55, 56, 57, 58, 61, 62, 67, 69, 70, 73-a, 74, 75-a, 75-b, 79, 80, 81, 82, 83, 84, 85, 86, 89, 91, 97, 102, 130-a, 131, 136.

The samples which fused between cones 27 and 32 inclusive were: Nos. 9, 16, 22, 23, 25, 27, 28, 29, 30, 37, 38, 44, 45 (1678), 46, 48, 51, 53, 59, 60, 65, 66, 71, 73-b, 73-c, 75, 77, 78, 87, 88, 90, 92, 93, 94, 95, 96, 98, 99, 100, 101, 121, 122, 129, 133, 134, X.

The samples which fused at cones 33 and above were: Nos. 11, 18, 26.

Porosities:—A grouping of the samples in accordance with their porosities at various cones is given in the following table:

5% or less at or below cone 5	5% or less between cones 5 and 9	5% or less between cones 9 and 12	5% or less between cones 12 and 15	10% or more at cone 12 or above
23	F	G	18	16
26	25	K[3]	38	46
29	27	49	54	50
30	28	51	56	70
42	37	73-a	65	75-a
55	37-a	75	71	79
57	52	90	74	84
58	66	96	77	89
59	81	97	87	94
60	86	....	92	98*
61	121	....	....	99
62	122	....	134	101
67	....	....	....	....
69	....	....	....	....
73-b	....	....	....	....
73-c	....	....	....	....
82	....	....	....	....
83	....	....	....	....
85	....	....	....	....
88	....	....	....	....
93	....	....	....	....
102	....	....	....	....
131	....	....	....	....

*Probably.

Strength tests:—The following are the transverse strength tests of the various clays reported in terms of the moduli of rupture in pounds per square inch. The symbol "p" is used to indicate results obtained in testing the clay only. The symbol "b" indicates the test of a mixture of equal parts of standard sand and clay; that is to say, the "bonding strength."

Sample	Below 200 lbs. per sq. in.		Between 200 and 400 lbs. per sq. in.		Above 400 lbs. per sq. in.	
	p	b	p	b	p	b
9	....	104.4	....	....	....	....
11	43.4	....	....	....	....	....
16	64.1	....	....	....	....	....
17	180.9	....	....	....	....	....
23	....	....	311.2	302.3	....	....
25	141.2	131.2	....	....	....	....
26	....	137.5	259	....	....	....
27	....	120.9	265	....	....	....
28	192	151.8	....	....	....	....
29	....	286.1	....	....	....	....
30	....	....	345	229	....	....

Sample	Below 200 lbs. per sq. in.		Between 200 and 400 lbs. per sq. in.		Above 400 lbs. per sq. in.	
	p	b	p	b	p	b
37	....	....	....	249.7	487.2	....
37-a	....	....	240.7	238.7	....	....
38	164.8	....	....	....	....	....
42	....	....	283.1	....	....	....
44	....	....	....	325.6	465.6	....
45	....	....	....	299.5	526.6	....
46	....	....	217.4	214	....	....
47	....	....	365.8	....	....	....
49	....	189.5	369.2	....	....	....
50	....	....	207	275.5	....	....
51	....	199	....	....	446.8	....
52	....	....	380.2	243.9	....	....
53	120.2	103.1	....	....	....	....
54	....	....	250	250	....	....
55	172.5	145.1	....	....	....	....
56	....	....	....	231.8	462	....
57	....	....	....	370	565.5	....
58	165.7	124.6	....	....	....	....
59	....	169.8	....	....	589	....
60	....	164.5	....	....	427	....
61	....	....	....	372.7	567	....
65	....	....	240.8	....	....	....
66	....	....	....	....	414.5	....
67	....	....	303.8	248.7	....	....
69	....	....	....	242	498.3	....
70	....	....	....	302.8	609	....
71	144	....	328	....	....	....
73-a	....	....	352.2	....	....	....
73-b	....	....	356.5	....	....	....
73-c	....	....	339.3	....	....	....
74	....	....	221.8	214.9	....	....
75	....	....	295.6	....	....	....
75-a	....	192	269.6	....	....	....
75-b	....	199.6	263	....	....	....
77	....	....	320	261	....	....
78	....	....	325.8	209.4	....	....
79	....	119.5	287.3	....	....	....
80	....	....	....	....	445.4	....
82	....	185.2	....	....	484.8	....
83	....	....	....	329	664	....
84	....	....	214	....	....	....
85	....	....	386.7	....	....	....
86	190.2	....	....	....	....	....
87	....	....	....	290.3	497.6	....
88	....	....	....	243	....	....
89	179	137.6	....	....	....	....

Sample	Below 200 lbs. per sq. in		Between 200 and 400 lbs. per sq. in.		Above 400 lbs. per sq. in.	
	p	b	p	b	p	b
90	....	....	....	290	420	....
91	....	....	309.5	236.7	....	....
92	....	....	201	....	....	....
93	....	....	302.5	....	554.7	....
94	140.6	....	....	....	....	....
96	....	107.3	277	....	....	....
97	....	....	....	201	565	....
98	....	149	....	246	....	....
99	....	107	215	....	....	....
100	....	....	....	222	475	....
101	....	177	....	....	532	....
102	....	....	297	223	....	....
121	191	123.3	....	....	....	....
122	177	136.5	....	....	....	....
129	....	....	....	247	795	....
131	....	192.6	361.8	....	....	....
133	....	59.6	....	....	....	....
134	....	194	....	....	442	....

SUMMARY

Grouping of Clays According to Uses

In the following summary the clays have been grouped according to uses to which they seem to be adapted. It is to be understood that the arrangement is based solely upon the data given, and not upon special tests.

Refractory clays burning to a porosity of 5 per cent or less at cone temperatures not exceeding cone 9:

Samples F, G, K3, Nos. 23, 25, 26, 27, 28, 29, 30, 37, 37a, 55, 59, 66, 73c, 88, 93, 121, 122.

Refractory clays which have a porosity of more than 5 per cent below cone 9:

Nos. 16, 18, 22, 38, 44, 45, 46, 49, 51, 53, 54, 56, 71, 75, 77, 78, 80, 87, 90, 92, 94, 96, 97, 98, 99, 100, 101, 129, 133, 134.

Stoneware clays:

Nos. 9, 23, 25, 26, 28, 29, 30, 37, 37a, 38, 41, 42, 44, 47, 49, 51, 52, 54, 56, 57, 65, 66, 70, 71, 73a, 73c, 74, 75, 75b, 77, 78, 79, 80, 85, 87, 88, 89, 90, 91, 92, 93, 96, 97, 100, 101, 121, 122, 134.

Architectural terra cotta clays:

Nos. 9, 23, 25, 26, 28, 29, 30, 37, 37a, 38, 41, 42, 44, 47, 49, 51, 52 53, 54, 55, 56, 57, 58, 60, 65, 66, 70, 71, 73a, 73c, 74, 75, 75b, 77, 78, 79, 80, 84, 85, 87, 88, 89, 90, 91, 92, 93, 96, 97, 100, 101, 121, 122, 134.

Sewer pipe clays:

Nos. 50, 57, 59, 60, 65, 67, 73b, 83, 86.

Face brick clays:

Nos. 42, 45, 47, 49, 50, 51, 52, 53, 54, 56, 57, 58, 59, 61, 62, 65, 67, 70, 71, 73a, 73b, 73c, 74, 75b, 77, 78, 79, 80, 83, 84, 85, 86, 87, 88, 89, 91, 92, 93, 96, 97, 98, 99, 100, 101, 134.

Common brick, tile, etc.:

Nos. 61, 62, 69, 75a, 81, 82, 86, 102, 131, 136.

Sanitary ware clays:

Nos. 23, 25, 26, 28, 29, 30, 37, 37a, 38, 41, 42, 44, 47, 49, 51, 52, 53, 54, 55, 56, 57, 65, 66, 70, 71, 73a, 73c, 74, 75b, 77, 78, 79, 80, 85, 87, 88, 89, 90, 91, 92, 93, 96, 97, 98, 99, 100, 101, 134.

OPTICAL FLUORITE IN SOUTHERN ILLINOIS[1]

By Joseph E. Pogue[2]

OUTLINE

ILLUSTRATION

INTRODUCTION

Fluorite, or fluorspar as it is commonly called, is a mineral of rather limited occurrence, used in bulk in this country in the manufacture of steel, hydrofluoric acid, enamels, glazes, and for a few other purposes. In addition, clear, colorless, or faintly colored specimens, such as occur rather sparingly in some localities along with the crude material, are suitable for the manufacture of certain types of lenses and prisms employed in microscopes and other optical instruments. Although the largest known deposits of fluorite in the world occupy a belt of country extending from southeastern Illinois into western Kentucky, but centering in Hardin County, Illinois, the availability for optical use of the product from this region has heretofore been neglected, and the United States has been dependent upon foreign sources for its material, which came largely through the hands of German optical dealers.[3]

In connection with a recent geological survey of the fluorspar deposits of southern Illinois, the State Geological Survey with this application in mind has determined the presence of optical fluorite of excellent quality and in quantity probably sufficient to supply the needs of the United States. This report is published for the purpose of bringing the matter to the attention of the industries concerned, with a view to stimulating a suitable production, now particularly needed as a result of the cutting off of foreign supplies by the war. The report is designed to be nontechnical in character and to supply the information essential to a proper development of this resource.

---

[1]Reprint of extract from Bull. 38, first published in 1918.

[2]In the field investigation upon which this report is based, the writer was assisted by L. W. Currier.

[3]Only two foreign sources of optical fluorite are known to the writer; these are Meiringen, Switzerland, and Obira, Bungo, Japan.

PROPERTIES, USES, AND VALUE OF OPTICAL FLUORITE

Each transparent mineral not only bends or refracts rays of light in a definite and characteristic manner, but bends the colored components of the individual rays at slightly different angles—a property called dispersion. In addition to this, most minerals break light into two rays, each of which is both refracted and dispersed; only minerals that crystallize in very symmetrical forms, such as cubes or octahedrons, do not show this double refraction. Fluorite bends light very slightly (has a low index of refraction); disperses light faintly (that is, its refraction of red rays differs only a little from its refraction of yellow rays and so on); and normally displays no double refraction. These three properties place fluorite in a unique position among minerals and fit it for a highly specialized optical use which no other mineral or artificial substance can meet equally well. Only three or four other minerals have lower refraction than fluorite; but these are either colored or are not sufficiently transparent, and moreover show marked double refraction as a result of their crystallization. Hence fluorite stands alone.

Glass, of a special kind, is the dominant material used in all optical apparatus. By varying the chemical composition of the glass and the shape of the lenses and prisms made from it, the various optical effects desired are obtained. Owing to the reflection of light from surfaces and a breaking up or dispersion of light in passing through a substance, errors are introduced, and to neutralize or minimize these errors calls for the best efforts of technical art and scientific knowledge. It is here that optical fluorite finds its chief use.[1] Due to its low refractive power and very weak color dispersion, this mineral is especially suitable for correcting the spherical and chromatic errors of lens-systems. The so-called apochromatic objective used with microscopes consists of a lens of fluorite placed between lenses of glass and represents the finest type of objective that optical art produces. There are two other classes of objectives, less fine and less costly, the *achromat* and the *semiapochromat;* fluorspar is used only in the second of these, which is a sort of compromise between the cruder achromat and the more nearly perfect *apochromat.* The less expensive semiapochromat could replace the apochromat in many instances, were optical fluorite more available; but at present the manufacturer is forced to conserve his meagre supplies of fluorite for use in making the finer and more expensive apochromats. It therefore appears that a plentiful supply of optical fluorite would be of great benefit to the microscope industry, as thus far the output of optical systems containing fluorite has been limited simply by an insufficient supply of this material. The development of adequate sources of optical fluorite therefore becomes a matter of considerable importance, affecting

---

[1]The writer is indebted to the Bausch and Lomb Optical Company, the Spencer Lens Company, and the Bureau of Standards for details in regard to the use of optical fluorite.

ultimately through cheaper and more efficient microscopes the progress of scientific and medical research.

Optical fluorite is also used in making prisms for spectrographs employed in ultra-violet work and for use in other optical apparatus in cases where great transparency to the ultra-violet and the infra-red parts of the spectrum is required. It is likewise employed as part of the lens-system in telescopes to correct certain color effects. Specimens suitable for such highly specialized uses as those mentioned in this paragraph are difficult to obtain, because of the comparatively large size of pieces required; but the demand for such material is rather limited in an economic sense, though very insistent and important for the furtherance of investigational activities. While practically all fluorite possesses the optical qualifications noted above, the vast preponderance of material is too strongly colored or else too clouded with internal fissures and inclusions to transmit light unaffected by these undesirable influences. Moreover, some clear and colorless specimens otherwise suitable for optical use are found to show an anomalous double refraction, due probably to abnormal conditions during crystallization, which renders them unfit. These incidental, rather than inherent properties, therefore, become the controlling factors in determining the availabilty of material, and consequently determine the practical specifications which prospective material must meet.

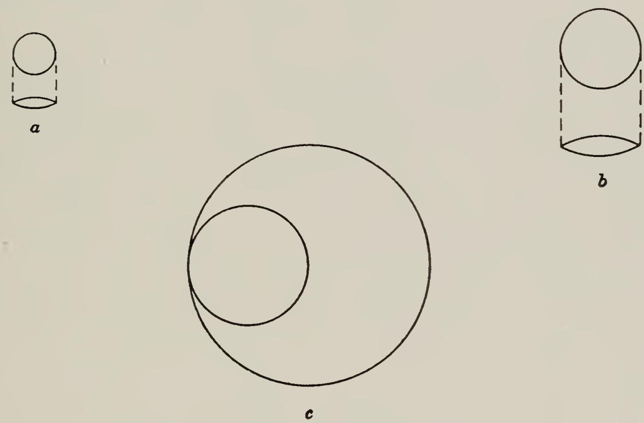


Fig. 57. Sketch.

FIG. 57.—Sketch showing the sizes of finished products made from optical fluorite: *a*, top and side view showing approximate size of smallest fluorite lens in common use; *b*, top and side view showing approximate size of largest fluorite lens in common use; *c*, approximate sizes of optical fluorite pieces used in special investigations.

For optical use a specimen of fluorite must contain a portion at least one-fourth of an inch in diameter, free from flaws, and colorless or nearly so. Crystals, or pieces bounded more or less completely by plane surfaces, are more likely to qualify than irregular masses. As the surfaces of most

crystals are dull, a corner of such a specimen should be broken off with a sharp blow so as to expose the interior. In doing this, it is desirable to rest the specimen on a wooden base and break off the corner along an incipient cleavage plane by means of a knife blade or chisel; such planes are usually present and may be located by moistening the specimen with kerosene. If the specimen looks promising, it is better to proceed no further, as fluorite is fragile and a misdirected blow will fill a clear piece with a network of fractures. A peculiarity of fluorite of optical quality is its conchoidal (irregularly curved) fracture and the absence of a strong tendency to break into pieces bounded by smooth planes in the fashion of the ordinary mineral.

An idea of the sizes involved may be gained from the accompanying figure, which shows the approximate sizes of the finished lenses. As to color, material that is absolutely water-clear is of course the most desirable, and in fact is essential for highly specialized uses; but faint tints of green, yellow, and purple do not in themselves render material altogether unsuited for optical use. Flaws must be lacking from the portion to be used, but flaws are present in the bulk of fluorite, due both to cracks (incipient cleavages) and to inclusions of bubbles or of visible impurities; accordingly the most detailed search is necessary to find pieces free from these objections. Moreover, careless handling, even jolts resulting from shipping, may develop flaws in clear material; hence the utmost care must be exercised in separating material of optical promise from its crude associations and in suitably packing such material.

The anomalous double refraction shown by some specimens, particularly by symmetrical crystal groups known technically as "twin-crystals," bars such material from optical use; but this property can be determined only by a microscope or other optical instrument at the eye of a trained observer. A clue to this condition is given in some cases by fine, parallel striations or rulings, marking a twinned condition of crystallization. In general, however, the clear specimens of southern Illinois fluorite already examined have been largely free from double refraction; hence for all practical purposes this test may be ignored in the field and left to the optical dealer to apply at his discretion.

The value of optical fluorite and the demand for it can not be expressed in definite figures, for the material is a specialized thing instead of a staple product. On the one hand, the demand will increase if optical fluorite can be produced at a figure sufficiently reasonable to warrant an enlarged utilization; whereas, on the other, an inflated price will destroy the opportunity for an increased demand. It must be remarked also that only a small portion, say 4 to 8 per cent on the average, of material classed as optical fluorite actually passes into the make-up of a lens-system, so much of the mass must be destroyed or discarded during manufacture. In other words, 25 pounds of good-looking, clear fluorite may produce no more than a single pound of finished lenses. Hence the value of the finished product comes

only in part from the value of the raw fluorite entering into it; much of its value is introduced by the skillful work essential to its manufacture. These statements are to obviate the assumption that crude optical fluorite is of gem-value. In order to make the matter more specific, fluorite qualifying as optical in quality is worth a dollar or more a pound, while particularly large and fine specimens have an individual value of $10 and more apiece. These figures are rough approximations only, designed to give prospective producers a general idea of what their product may be expected to yield but not to be taken as quotations of market prices.

As to the quantity of optical fluorite that the United States consumes each year, it is likewise difficult to state, as this depends upon the quality of the crude material. But as prospective producers should have some idea of both the normal and the potential demand for their product, it may be assumed for this purpose that several hundred pounds of optical fluorite will meet the normal yearly demand, while this figure can perhaps be doubled or even more greatly increased if additional supplies can be reasonably produced.

OCCURRENCE OF OPTICAL FLUORITE

While ordinary fluorite is of common occurrence in the fluorite region of southern Illinois, it is only here and there that specimens of optical quality are found in association with the cruder material. While the presence of the optical fluorite seems to favor certain specific localities and to shun the large and extensively worked veins, a familiarity on the part of the mining men of the region with the requirements for optical use will undoubtedly bring to light further occurrences of promise.

The ordinary fluorite occurs in two ways: (1) as nearly vertical veins cutting bedded rocks along fault planes, and (2) as horizontal beds in part replacing limestone members of the bedded rocks. Optical fluorite has been found in association with each type of occurrence, but the second has thus far given the greater promise. Material of optical quality is more likely to be found as cubic crystals occupying the walls of small open spaces in the veins or beds, particularly in places where such cavities are relatively numerous and indicate a leisurely process of formation, than along with fluorite that is massive or tightly developed in the surrounding rock.

The mines and prospects that have been determined to contain material of optical quality are as follows:

The Cave in Rock mine, near Lead Hill, Hardin County, Illinois; operated by the Glass Brick Company, 241 Walnut St., Cincinnati, Ohio; a bedded deposit containing pockets lined with fluorite crystals, some yielding material of optical quality, colorless to faint yellow, and characterized by a conspicuous conchoidal fracture. This mine could probably be made to yield from one hundred to several hundred pounds of optical fluorite per year if continuously and actively worked.

Several prospects, or small mines, operating in 1917, on the west side of Lead Hill, in NW. ¼ SW. ¼ sec. 4, T. 11 S., R. 9 E., Shawneetown quadrangle, contain

optical fluorite similar in character to that described above. One property is owned by the Lead Hill Lead and Spar Company; another by C. M. Miller, Basic Mineral Co., Pittsburgh, Pa.

The Pierce mine, in sec. 34, T. 11 S., R. 7 E., Equality quadrangle, operated by H. B. and Walter Pierce, Golconda, Illinois, has made shipments of optical fluorite in the past.

The Rose mine, in sec. 30, T. 11 S., R. 8 E., Equality quadrangle, not now (1917) operated; owned by D. C. Peyton, Indiana Reformatory, Jeffersonville, Indiana; contains some material of promise.

LIST OF PROSPECTIVE PURCHASERS

For the information of prospective producers of optical fluorite, the following names may be given as among the possible purchasers of this material:

Bausch and Lomb Optical Co., Rochester, N. Y.

Spencer Lens Co., Buffalo, N. Y.

Bureau of Standards, Washington, D. C.

Ward's Natural Science Establishment, Rochester, N. Y.

SUGGESTIONS AS TO DEVELOPMENT

The fluorite region of southern Illinois appears to be capable of supplying the needs of the United States in respect to optical fluorite. This will be accomplished if the mining interests of the region will give instructions to their mining staffs to search for and save all clear, glassy-looking specimens. No special knowledge is required to recognize material of promise. As compared with developed mines, the small mine or prospect has an equal if not a better chance of yielding good material, and hence the matter concerns the one-man operator as well as the larger mining company. Prospects in the neighborhood of Lead Hill should be examined with particular thoroughness, as this locality offers more than ordinary promise. Great care should be exercised in breaking large specimens for examination; also in further handling, packing, and shipping. Specimens for shipment should be packed in cotton, excelsior, or other resilient material, and placed in wooden, and not pasteboard, boxes. Samples of material of promise should be submitted to prospective purchasers before shipments are made. Particularly fine specimens will find a sale as single items; but the general run of optical fluorite should be offered for sale only in lots of several pounds or more.

For the proper development of this resource, which, though of limited value from a financial standpoint, is of considerable importance to society, the optical companies will bear in mind that the producers must be encouraged by a consistent price and at the outset be helped in discriminating

between material of optical and common quality; while the producers will appreciate the fact that they are handling a highly specialized product, whose value can be more substantially enhanced by encouraging an enlarged demand through a suitable production than by limiting the supply and holding out for prices discouraging to the manufacturer.

THE ILLINOIS PYRITE INVENTORY OF 1918

By G. H. Cady

OUTLINE

ILLUSTRATION

NATIONAL SULPHUR SITUATION

With the entrance of the United States into the war in 1918 and with the reduction in the importation of Spanish pyrite that followed, the increased requirements of raw material from domestic sources for use in the manufacture of sulphuric acid became a matter of some concern. The production of sulphuric acid (monohydrate) in 1917 was about 4,300,000 tons, against about 3,900,000 tons in 1916. We imported from Spain and Portugal in 1917 about 833,000 tons of pyrite which may be reckoned as equivalent of about 1,000,000 tons of sulphuric acid (monohydrate); so that from domestic and Canadian resources we manufactured in 1917 about 3,300,000 tons of sulphuric acid. The government estimated a requirement of 5,000,000 to 5,600,000 tons in 1918. It appeared necessary, therefore, to find raw material in 1918 sufficient to manufacture about 2,300,000 additional tons of acid.

A careful review by government agencies of the possible sources of raw material revealed what seemed early in 1918 to be incapacity of then existing sources to meet the probable demand. Sulphuric acid is manufactured in three ways: from native sulphur or brimstone; from pyrites; and as a by-product in smelting and refining. In 1917 brimstone used in the manufacture of sulphuric acid amounted to 463,364 tons producing possibly about 1,300,000 tons of acid (monohydrate); from 1,257,128 tons of pyrite about 2,000,000 tons of acid were produced; and by-product acid to the amount of about 1,000,000 tons was manufactured, mainly in the western states—a total, as has been stated, of about 4,300,000 tons With about 800,000 tons of Spanish pyrite cut off the market and a probable additional

demand for raw material sufficient for about 2,300,000 tons of acid, there was an apparent need for the stimulation of the industry and the discovery of additional sources of raw material. It was also obvious that because of the high freight rates from the western smelters, the industry would have to depend largely upon the brimstone and pyrite producers for the necessary raw material.

When the importations of Spanish pyrite were restricted, naturally the acid manufacturers turned to the most available source of supply—the sulphur or brimstone deposits of Louisiana and Texas, but it became a matter of doubt whether these deposits were adequate to the need.

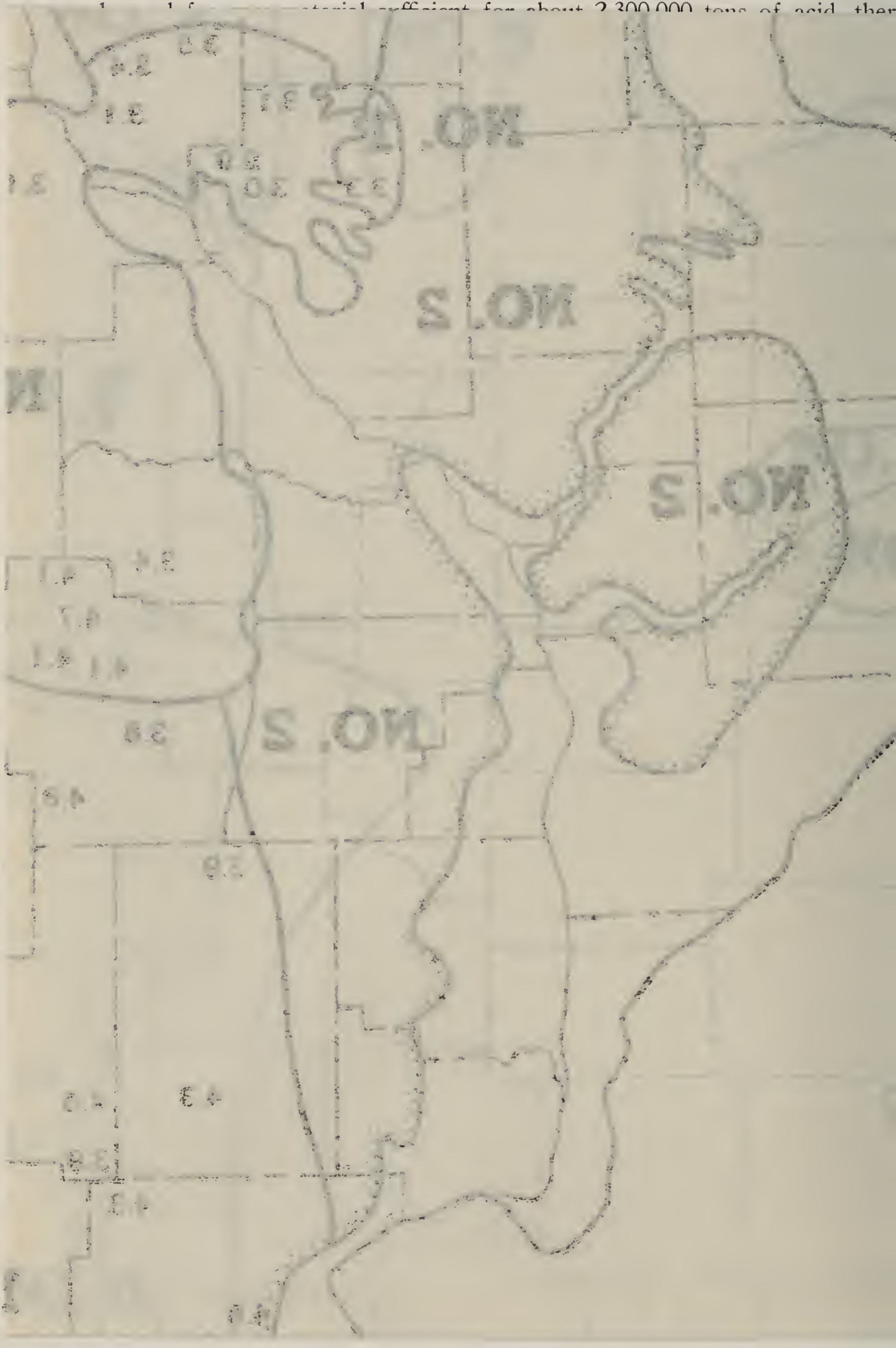
In view of what was interpreted to be an impending shortage of brimstone, the availability of pyrite resources became a matter of investigation. Pyrite in the central and eastern states was of especial interest because of its nearness to the acid plants. In this part of the country it occurs as "coal brasses" in coal mines and as mineral deposits in certain states such as Missouri, Virginia, Georgia, and Wisconsin. Under the influence of interest stimulated by war committees, such as the War Minerals Committee, the U. S. Bureau of Mines in coöperation with the geological surveys of several states instituted an extensive inventory of the pyrite resources of the central and eastern states. The coal-producing states were given special attention, because of the recognized importance of the coal mines as the most probable source of large quantities of pyrite.

As a result of this investigation carried on in the coal fields under the direction of Mr. E. A. Holbrook, of the U. S. Bureau of Mines, it is now known that the coal mines of Pennsylvania, Ohio, Kentucky, Indiana, Michigan, Illinois, and Missouri can easily furnish, with the equipment now available, up to more than 2,000,000 tons of pyrite annually, and that the mines of Illinois, on a very conservative estimate, could easily produce 200,000 tons without additional equipment. During 1917 this State produced about 24,000 tons, an amount probably not over 1/10 of what it could easily produce. Indeed, with additional rather inexpensive equipment, the output could be increased very materially beyond 200,000 tons, probably nearly 500,000 tons annually, a figure which is essentially the amount of the pre-war demand for pyrite from domestic sources.

That stimulation of the pyrite industry has not resulted from the growth of war industries has been somewhat of a surprise. Events have shown, however, that the country possesses larger resources of brimstone than could have been suspected at the time the pyrite inventory was inaugurated. New areas have been opened to development, and new wells have been drilled on the original properties, so that at the opening of 1919, it was a serious problem to find a market for the prospective production of brimstone. In fact, as early as July, the War Industries Board issued the statement that there were above ground at the mines in Louisiana and Texas, over 1,000,000 tons of brimstone—a sufficient stock for eight months at the

rate of 120,000 tons a month, which

material sufficient for about 2,300,000 tons of acid, ther



rate of 120,000 tons a month, which was approximately the current demand, according to one authority. There was the additional uncertainty, however, in regard to these deposits that was occasioned by their location near the coast, thereby making them possible targets of marauding German vessels that might escape into the Gulf. In general, however, uneasiness in regard to a possible sulphuric acid shortage had disappeared in the latter part of the summer, even before the pyrite inventory had been completed in all the states.

PYRITE SITUATION IN ILLINOIS

The pyrite inventory in Illinois, as well as in the other states, can most properly be looked upon as insurance against a possible contingency. Yet so far as Illinois is concerned, it will possibly lead to some benefits to the coal trade on a peace basis.

It has been shown that pyrite can be recovered at washeries at a very small expense. The expense involves the installation and operation of one or two more jigs where the refuse is washed to recover the pyrite, the refuse itself being furnished without cost as a product of the coal washery. At least one coal washery has installed a pyrite-recovery section during the last year. Others would probably find it profitable to do the same.

The pyrite inventory has also furnished a more systematic body of information relative to the distribution and occurrence of pyrite than heretofore has existed. The investigations of the pyrite resources and the search for low-sulphur coal in connection with the work on gas coals performed by the Gas Section of the Illinois Mining Investigations have together furnished information relative to the distribution of sulphur and pyrite that is doubtless of sufficient general interest to warrant brief comment.

Distribution of Pyrite

The accompanying map, Plate III, shows the Illinois coal basin and also the areas wherein the various coals are mined.

The actual sulphur content of the coals of the State, as determined by analyses of face samples, differs in a conspicuous degree only as between coals of southern Illinois and coals of central and northern Illinois. Small black figures on the map show the average sulphur content of the coal at about 100 representative mines, as determined by three or more analyses of face samples at each mine. There is possibly a variation of about 1 per cent in the sulphur content among the coals north of Jackson, Jefferson, and Saline counties, except for Mercer and Rock Island counties. The northern coals generally have between 3.25 and 4 per cent of sulphur, but the Rock Island and Mercer County coal (No. 1) has an unusually high sulphur content, varying from 4.25 to 5.02 per cent.

In the southern counties, Jackson, Williamson, southeastern Perry, Saline, and Gallatin, the sulphur content averages 1 to 2 per cent less than

it does to the north, varying from about 1 to 2.75 per cent. In the lighter shaded areas shown on the map in Franklin, Williamson, and Jackson counties, the sulphur content averages below 1.5 per cent, and in the darker area below 1 per cent. The low sulphur content of the southern Illinois coals is one special reason for their greater desirability among the coals of the State for domestic as well as for gas-making purposes. It should be stated, however, that coal from other parts of the State, if properly prepared at the mine, could probably be used with equal satisfaction by the householder, thus reserving the low-sulphur coal for industrial uses, to which it is specifically adapted.

Form of Occurrence

In general, the low-sulphur coals, i. e., those containing less than 3 per cent of sulphur, do not contain much pyrite in free or nodular form, and therefore very little recoverable pyrite. And the higher sulphur coals, although they all contain free pyrite in some form, do not always contain it in recoverable form. Its ease of recovery may in fact be taken as an index of the ease with which clean coal can be furnished at the shaft head. The ease of recovery, furthermore, can by no means be inferred from the coal analysis, but can be determined only by an inspection of the coal at the face in the mine.

Most of the pyrite occurs in one of three forms: (1) as nodules or balls; (2) as sheets or thin lenses in the parting between benches; and (3) as lenticular masses fingering laterally into the coal. Coals differ somewhat characteristically in regard to the form of pyrite most commonly found in each bed. Thus, No. 2 coal in northern Illinois has free pyrite most commonly in the form of nodules of brassy, metallic-like, massive sulphide. No. 5 coal in the Peoria-Springfield district has pyrite balls of the same sort in the upper coal, but more characteristic are what are known as the brown or gray sulphur lenses. These are lenticular or irregular masses of banded stony pyrite that finger laterally into the coal. No. 6 coal is distinctly a bedded coal, separated into three or more persistent benches. The pyrite is most commonly found as plates or thin lenses in the parting between the benches. No. 7 coal carries a large amount of pyrite as irregular lenses of massive stony sulphide much like that found in No. 5 coal, but not commonly banded.

Recovery

Pyrite can be recovered in two places: at the coal face by the miner and loader; and at the tipple either by pickers, or by mechanical dry separation or by washing the coal. Recovery at the tipple is probably the most efficient method, but the coal should also be picked at the face to remove the larger pyrite nodules, if the pyrite is to be marketed.

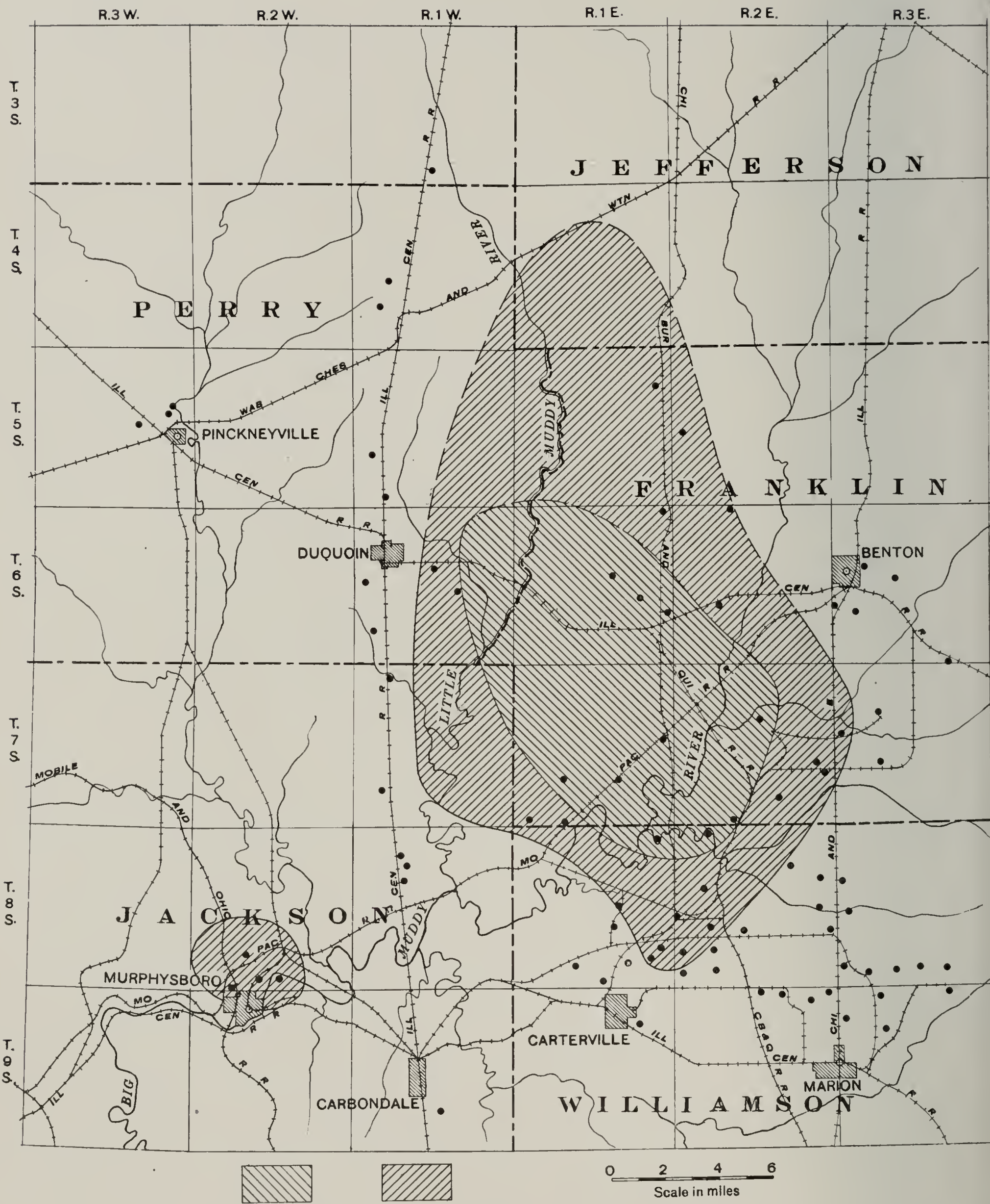
The ease of recoverability of the different forms of pyrite varies. The more easily the pyrite can be recovered, the cleaner the coal that can be

produced without special facilities for treatment at the tipple. Large nodules of bright pyrite such as are found in No. 2 coal are easily seen by the miner, and relatively easily removed. Irregular lenticular masses "frozen" to the coal, such as are found in No. 5 and No. 7 coals, are not readily removed, and the miner is too much inclined to throw chunks of coal containing such lenses into the car, risking possible discovery at the tipple, and the resulting fine. Too frequently this is a very slight risk. Sheet pyrite is easily hand-picked when thick enough to resist the shattering incident to mining. When thin, however, it breaks into small pieces and forms accordingly a considerable part of the fine coal or screenings and can be removed only by mechanical separation of some sort.

If pyrite is to be considered as an impurity to be discarded rather than a commodity to be saved, as apparently it must continue to be regarded until its recovery becomes a matter of economic importance, the investigations have indicated that more systematic efforts than have been in force in the past should be instituted to eliminate this material from the coal before it is furnished to the public. Certainly the material has not been removed from the coal nearly as effectively as it might be, nor possibly have the means adopted in individual cases been especially applicable to the form of pyrite present. Some blame attaches to the miner for not obeying the rules and to the operator for not enforcing the rules in regard to clean coal. But a large part of the blame attaches to the general public in not insisting that all coal be subjected to some adequate form of preparation at the tipple.

SUMMARY

The pyrite inventory in Illinois has served its immediate purpose of furnishing the nation definite data concerning its supply of one of the essential war minerals. Aside from furnishing desired information along the original lines of the investigation, the pyrite inventory has some economic bearing upon the industry in the normal times of peace. In connection with search for low-sulphur coal, it has effected a definite delineation of areas of coal suitable for special purposes, such as the manufacture of metallurgical coke and city gas. It has also furnished information relative to the varieties of free pyrite found in the higher sulphur coals which possibly may lead to a better understanding of the various conditions affecting the production of clean coal at the shaft head. This information is preliminary to a more systematic adaptation of the means of cleaning coal to the varying conditions of occurrence of the impurities, the elimination of which is desired. The pyrite inventory was an investigation conducted to safeguard the public. It had uncertain commercial application and was of such a nature that private capital could only with difficulty have been found to carry it through. It is such services that can best be accomplished with public funds such as are allotted to the State Geological Survey.



Coal containing less than 1 per cent sulphur.

Coal containing less than 1.25 per cent sulphur.

Fig. 58. Location of the area of low-sulphur coal in Illinois.

LOW-SULPHUR COAL IN ILLINOIS[1]

By Gilbert H. Cady

Extensive sampling of coal in Illinois during the past ten or twelve years by the State Geological Survey in coöperation with various organizations, such as the U. S. Bureau of Mines, the University of Illinois, and the Illinois Coöperative Mining Investigations has made possible the delineation of two areas of low-sulphur coal in Illinois, both areas being located in the southern part of the State. The sulphur content of these coals is less than 1.25 per cent, so that if otherwise suitable, they can be employed for metallurgical uses and for the manufacture of water-gas and retort gas. One of these areas is small and lies in Jackson County near Murphysboro; the other is much larger and includes a large part of the famous Franklin County field.

A small area of No. 2 or Murphysboro coal has been worked for many years near the town of Murphysboro, Jackson County, Illinois. In two mines, at least, operating in this field the coal has a sulphur content of less than 1.25 per cent. It is doubtful, however, whether this field will ever be a source of large tonnage of low-sulphur coal, as the total area underlain by this coal in workable thickness is probably less than fifteen square miles, and a large part of it has already been worked out.

The location of the area of low-sulphur coal in the Franklin County field is shown in the accompanying map (fig. 58). The small area underlain by the Murphysboro low-sulphur coal is shown near the town of that name in the central part of Jackson County. The larger area lies in the west side of Franklin County, extending also about six miles south into Williamson County, about four miles west into northern Jackson and western Perry County, and northward an undertermined distance into Jefferson County. All but the northern limit of the area is fairly well defined by sampling in numerous mines. The inner cross-lined area is underlain by coal having less than 1 per cent sulphur; the outer boundary surrounds the area underlain by coal having less than 1.25 per cent sulphur.

The coal mined in the district is No. 6 or Herrin coal, commonly known as the Carterville or Franklin County coal. The bed has a thickness varying from about eight feet on the border of the lower sulphur area up to more than ten feet in the central portions, locally having a thickness of fourteen to fifteen feet. The sulphur content in general decreases as the thick-

---

[1]This is a reprint of a paper presented by Mr. Cady before the American Institute of Mining and Metallurgical Engineers, at their Chicago Meeting, September, 1919. The paper was first published in 1920 in Vol. LXIII, pp. 641-643 of the Transactions of that society.

Analyses of many Illinois coals and additional information on low-sulphur coal will be found in the following bulletins obtainable from the State Geological Survey:

Parr. S. W., Purchase and Sale of Illinois Coal on Specification: Ill. State Geol. Survey Bull. 29, 1914.

Cady, G. H., Mines producing low-sulphur coal in the central district: Ill. Co-operative Mining Investigations Bull. 23, 1919.

ness of the coal increases. A further peculiarity is a variation of the character of the roof accompanying the variation in thickness, for near and beyond the border of the low-sulphur area there is a limestone cap rock within about twenty-five feet of the bed, whereas the cap-rock is either absent or at a much greater height above the coal in the central part of the area. This relationship between the roof rock, the thickness of the coal, and the amount of sulphur present seems to hold consistently throughout the field. There is also a decrease in the interval between No. 6 and No. 5 coals and an increase between No. 6 and No. 9 coals operating geographically across the Franklin County field the same as the decrease in the sulphur content.[1] These stratigraphic variations accompanying the chemical variation make it possible to estimate roughly the character of the coal even from drill records and to determine the approximate extension of the field in areas not yet mined.

[1]Cady, G. H., Coal resources of District VI: Ill. Co-operative Mining Investigations Bull. 15, pp. 29-47, 1916.

NOTES ON POTASH POSSIBILITIES IN ILLINOIS

By C. R. Schroyer

OUTLINE

TABLES

GREENSAND DEPOSITS OF SOUTHERN ILLINOIS

A bed of greensand has been found in Pulaski County, two miles above Olmsted, on the farm of James A. Barber in sec. 13, T. 15 S., R. 1 E. Other beds are present, as shown by wash from partially covered cliffs in the same vicinity, as well as by reliable reports of deposits covered by water at the time of the examination. Such deposits were also mentioned at "Chalk Bank," a cliff facing Ohio River on the Barber farm, and at Hillerman's Landing, in sec. 16, T. 15 S., R. 3 E., Massac County.

A section measured in a ravine three-quarters of a mile back from Chalk Bank is as follows:

Section of greensand on the Barber farm, near Olmsted	*Feet*
Clay shale of a drab color	10
Greensand; grades into clay shale above	4
Conglomerate and sand, small quartz pebbles cemented by iron	1
Greensand with few quartz pebbles	3½
Clay shale, impure	3

This bed is well above the highest water mark and fifty to sixty feet above the low-water level in Ohio River. It is also exposed in several of the near-by gullies. Tunneling would be the most economical way of recovering the greensand, although considerable quantities could be obtained by shallow surface workings.

Chemical analysis by the Department of Chemistry of the University of Illinois gave the following results:

Table 45.—*Partial chemical analysis of Illinois greensand*	*Per cent*
SiO_2	74.76
K_2O	6.22
CaO	.48

In a separate determination made by the Department of Agronomy the phosphoric acid content was found to be about 1/10 of 1 per cent.

New Jersey greensand has higher phosphoric acid and calcium carbonate content, but averages lower in silica, and about the same in potash. The richer New Jersey beds analyze from 5 to 7 per cent of potash, but many beds contain as low as 3 per cent or less.[1]

Samples from New Jersey and Delaware yield from 3.50 to 7.15 per cent of potash; from Maryland, 4.45 per cent, or less; from Virginia, samples rich in lime yield 2 to 2.5 per cent; from North Carolina, 2.96 per cent or less; and those from Arkansas, 4.90 per cent or less. The phosphoric acid content ranges from .62 to 7.35 per cent, generally being about 1.5 per cent. All modern analyses indicate that glauconite contains only 7 to 8 per cent of potash.[2]

The total thickness of this deposit is not known, nor the thickness of any but one of the higher beds. Shallow drilling might well be expected to show an Illinois deposit of such extent and location as to attract potash producers, once that industry has passed the present experimental stage. It is unlikely that the thickness of the deposit will approach that of the New Jersey beds, many of which are twenty or more feet thick. However, very few of the thicker beds in New Jersey are rich in potash.

According to information furnished by the United States Geological Survey and by H. B. Kümmel, State Geologist of New Jersey, three companies are now producing or preparing to produce potash from greensand: the American Potash Company (formerly the Kaolin Products Corporation), at Jones Point, New York; the Atlantic Potash Company, of Stockerton, Pennsylvania; and a third company with Dr. F. Tschirner in charge, at Medford, New Jersey. None of these companies has progressed far beyond the experimental stage.

Various processes are being tried for the recovery of the potash. The Atlantic Potash Company extracts by the Von Kolnitz process. In brief, this consists of heating the marl with calcium chloride in rotary kilns, the leaching of the resulting potassium chloride from the calcined mass, and finally its precipitation. Another process consists of digesting under pressure finely ground greensand with lime and water, thereby obtaining caustic potash of remarkable purity, and at the same time converting the residue into a material of value for sand-lime brick. The operation is carried out with high-pressure steam (225 pounds for 2 to 14 hours). It has developed from this process that greensand does not react like a true potassium-iron-silicate, but that it is probably a potassium-iron compound involving free silica, but not a silicate. From 70 to 80 per cent of the total potash is considered a satisfactory yield. The residue is to a degree self-cementing, and when subjected to steam pressure cements sand so firmly that small enclosed pebbles fracture before the bond gives way. Sand-lime brick, the important by-product, are of good quality and find a ready market.

---

[1]Reports of the Geological Survey of New Jersey.
[2]Ashley, Geo. H., U. S. Geol. Survey Bull. 660-B, p. 29, 1917.

POTASH AS A BY-PRODUCT IN CEMENT MANUFACTURE

Processes in Use

Potash has also been produced from cement dust by the Cottrell[1] process. This consists, in brief, of catching and concentrating the volatilized potash by the electrical precipitation of the dust in cement mills. Further concentration is accomplished by reburning the accumulated dust with sufficient raw material to balance the feed.

Other processes have been proposed:[1] One by S. B. Newberry is based on the principle that the alkali content in cement clinker is practically constant, irrespective of the proportion of alkalies in the raw mixture. This content may be reduced to a minimum by increasing both the temperature and the time of exposure to high heat beyond that ordinarily employed. A large part of the alkali may be recovered from the stack gases by bringing them into intimate contact with sprays of water or by passing the gases through a space fitted with porous material, the surfaces of which are kept wet with water. The smaller part of the alkali, which is soluble, is removed from the resultant mix, and the insoluble mud is recharged into the kiln with fresh raw material, thus increasing the alkali content of the stack gases and the relative amount of soluble alkali in the water-chilled solution. Another process, originated by Samuel Peacock,[1] consists in treating the flue dust with a hot monocalcium phosphate solution, thereby obtaining potassium phosphate and calcium silicate.

Illinois Shales of Possible Interest in Cement and Potash Production

CHEMICAL CHARACTER

The interest which this possibility for potash production may have to Illinois cement producers is evident from the analyses of the following shales, most of which are suitable for use in Portland cement.

Table 46.—*Potash content of Illinois shales*

Location	Potash (K_2O) *Per cent*
Alton	3.28
Albion	3.82
Springfield	2.88
Edwardsville	2.03
Galesburg	2.60
Streator	2.80
Danville	2.90
Danville	2.94
Jonesboro[2]	5.48
Dixon	5.8

[1]Phalen, W. G., Min. Resources of U. S., 1915, Pt. II, pp. 122-124.
[2]Average of nine samples.

The first eight analyses given above are reprinted from a report by A. V. Bleininger.[1] The last two are taken from a joint publication of the Division of Applied Chemistry of the University of Illinois, the Illinois State Geological Survey, and the Agricultural Experiment Station.[2] In this publication Parr and Austin have the following to say about the potash possibilities of Illinois shale in general and about the Jonesboro black shale in particular:

"The Illinois shales that we are here considering, instead of having an average potash content of 2 or even 2½ per cent, have a content of 5 per cent in the raw state. They compare, therefore, very favorably with the greensands of New Jersey, concerning which not a little consideration is now being given both in the literature and financially, as a possible source of supply for this important product.[3] The first question that naturally arises, therefore, relates to the suitability of these Illinois shales with reference to their main constituents for the purpose of compounding into a suitable cement mix. The best authority on this phase of the topic is Professor A. V. Bleininger, who in his study of Illinois shales for cement-making,[4] gives analyses for eight samples which he deems suitable for such a purpose.

"They show so little variation in composition that for purposes of illustration in this discussion they may be fairly represented by an average value for each constituent. These values are given in the second column of Table 47. For comparison, therefore, as to their suitability along cement lines, two of the high-potash shales are shown in parallel columns 3 and 4.

TABLE 47.—*Comparison of Illinois shale constituents with reference to their cement-making properties*

	Average of eight Illinois shales (Bleininger)	Sample No. 1 Illinois potash shales	Sample No. 2 Illinois potash shales
	Per cent	*Per cent*	*Per cent*
SiO_2	61.56	53.8	55.0
Al_2O_3	16.12	17.7	16.3
Fe_2O_3	2.96	5.8[5]	6.0[5]
Fe O	3.52	....	....
CaO	0.94	0.7	0.3
MgO	1.79	1.8	1.5
K_2O	2.90	5.0	4.9
Na_2O	0.82	0.5	0.4
Ignition loss	6.72	11.9	13.0

[1]Bleininger, A. V., Portland cement resources of Illinois: Ill. State Geol. Survey Bull. 17, p. 101, 1912.

[2]Parr, S. W., Austin, M. M., Krey, Frank, and Stewart, Robert, Potash shales of Illinois: University of Illinois Agricultural Experiment Station Bull. 232, March, 1921.

[3]Chem. and Met. Eng., 22, 815, 1920.

[4]Ill. State Geol. Survey Bull. 17, p. 101, 1912.

[5]Total iron calculated to Fe_2O_3.

"Probably the most characteristic feature of this table from the cement-making standpoint is the ratio between the silica (SiO_2) and the alumina (Al_2O_3). According to the average American practice, this ratio should fall between 2.5 and 3.5. Upon calculating these ratios for shale samples Nos. 1 and 2 of the table, we have:

$$\text{Shale No. 1} \qquad \frac{53.8}{17.7} = 3.02$$

$$\text{Shale No. 2} \qquad \frac{55.0}{16.3} = 3.37$$

"Hence, it is evident that on the basis of the silica-alumnia ratio the two samples of the potash shales under consideration are seen to be in the most advantageous zone.

"Since, in the process of compounding to produce a suitable cement clinker, a shale is mixed with from two to three times its weight of limestone, it follows that the percentage of K_2O in the raw mix is correspondingly reduced. In the average American practice this factor amounts to from 0.7 to 1.0 per cent, and on this basis with a 66⅔ per cent recovery of the total potash there would result an average yield of about 2.9 pounds of K_2O per barrel of cement made. On the same basis the potash shales as given in columns 3 and 4 of Table 47 should show a yield of 5.4 pounds per barrel.

"On this basis, estimating the price of potash at 15 cents per pound, the shales here studied would return a value for the potash recovery alone of 82 cents per barrel of cement made, as against 19⅓ cents recovery from the average potash content of the ordinary raw cement mix."

In this same connection Parr and Austin make the statement that although the potash of the Dixon shale is held in chemical combination in a somewhat different manner than is that of the Jonesboro shale, "it is true that in the process of cement manufacture the potash would be equally recoverable in either case."

NOTES ON OCCURRENCE

The eight Illinois shales used for the averages in column 2 of Table 47 are all of Pennsylvanian age. Such shales are widely distributed throughout the Illinois coal basin.

The Dixon shale is the green Decorah shale of Ordovician age. This shale is of variable thickness, ranging from a few inches to 25 feet, and is generally to be expected at its proper horizon at the top of the St. Peter sandstone just below the base of the Platteville limestone. Another thin horizon of greensand has been noted between the base of the St. Peter sandstone and the top of the Lower Magnesian limestone. Both of these horizons are broken and irregular in distribution and thickness because of the

unconformable relation of the St. Peter sandstone both above and below. One section along Pecumsaugan Creek, La Salle County, according to field notes of Gilbert H. Cady, shows two feet three inches of such clay, with occasional lenses through a vertical section of nine and a half feet.

The shale from the vicinity of Jonesboro is the Devonian (Mountain Glen) shale which is 35 to 40 feet thick as it outcrops a mile or two west of a line between the towns of Jonesboro and Mountain Glen, in a narrow belt seven miles long. Although in most places either the outcrop is in a comparatively inaccessible position or else the overburden is of prohibitive thickness, there are several localities where the shale might be economically mined. In Part II of Bulletin 232 previously cited, a more extensive description of the occurrence of the shale and the feasibility of its production, will be found.[1]

[1]Krey, Frank, Geology, distribution, and occurrence of the potash-bearing shale of Union County: Agricultural Experiment Station Bull. 232, Part II, pp. 237-243, 1921.

NOTES ON ILLINOIS BITUMINOUS SHALES, INCLUDING RESULTS OF THEIR EXPERIMENTAL DISTILLATION

Compiled by N. O. Barrett

OUTLINE

ILLUSTRATIONS

TABLES

INTRODUCTION

Not infrequently the Survey receives inquiries about the possible value of Illinois shales and cannel coals as sources of oil and gas, and it is to satisfy such inquiries that this paper has been compiled. Deposits of assured commercial value are unknown, but certain of them have been carefully tested and have proved so promising that publication of the results, together with notes on other miscellaneous deposits is considered worth while.

The sources of the information are various, but full references are given in the footnotes, and acknowledgment is here made of the free use of the reports and notes on which the compilation is based.

Many of the black and dark-brown shales of Illinois owe their color to their content of bituminous or carbonaceous material and most of them, if heated, will yield oil, gas, and other similar products, at least in small amounts. Strictly speaking, the term "oil shale" should probably be reserved

FIG. 59. Index map showing the location of shales and cannel coals in Illinois, about which some information is available regarding the amount of oil they would produce upon destructive distillation.

for carbonaceous shales which are rich enough to have possible commercial value as sources of oil and gas. In this report, however, the term "oil shale" is used in a very general way, as most of the deposits described do not have a sufficient content of hydrocarbon to deserve the name, and might better be called simply carbonaceous or bituminous black shale.

SUMMARY

In Illinois dark brown or black carbonaceous or bituminous shales are found to some extent in the Ordovician and Devonian systems, but it is in rocks of the Pennsylvanian system that such shales are particularly widespread and abundant. Figure 59 shows the outlines of the area underlain by Pennsylvanian strata, and therefore the area in which black shales similar to those described for Schuyler, Sangamon, and Moultrie counties are not uncommon. Apparently, however, it is only locally, as in Johnson County, that the Pennsylvanian black shales approach commercial value as sources of oil and gas.

The outcropping Ordovician bituminous shales are merely a local development and are too thin to be of value; and the Devonian black shales of Union County will probably be of considerably more value as a source of potash[1] than as oil shale.

All the available information about such Illinois shales as have been tested is covered in the following pages. For convenience the material is arranged by counties.

JO DAVIESS COUNTY[2, 3]

Character and Distribution of the Oil Rock

The general distribution of the bed known commonly to drillers in extreme northwestern Illinois as "the oil-rock" is shown in figure 60. It is a laminated bituminous shale which when wet is light gray. Seldom is it much more than a foot thick though in an abandoned mine two miles west of Platteville it reaches its maximum known thickness of three feet.

Results of Tests

"The oil-rock is very porous and light, having a specific gravity of only 1.98 and yielding gas bubbles when placed in water. One volume of the rock gave 57.46 volumes of gas when heated to a red heat in a vacuum for two hours. A gas analysis of this material gave the following results:

[1]Parr, S. W., and Austin, M. M., Potash shales of Illinois; Krey, Frank, Geology, distribution, and occurrence in Union County; Stewart, Robert, Finely ground shale as a source of potassium for soil improvement: Univ. of Ill. Ag. Exp. Sta. Bull. 232, 1921.

[2]Cox, G. H., Lead and zinc deposits of northwestern Illinois: Ill. State Geol. Survey Bull. 21, pp. 24-30, 1914.

[3]Trowbridge, A. C., and Shaw, E. W., Geology and geography of the Galena and Elizabeth quadrangles: Ill. State Geol. Survey Bull. 26, pp. 45-47, 1916.

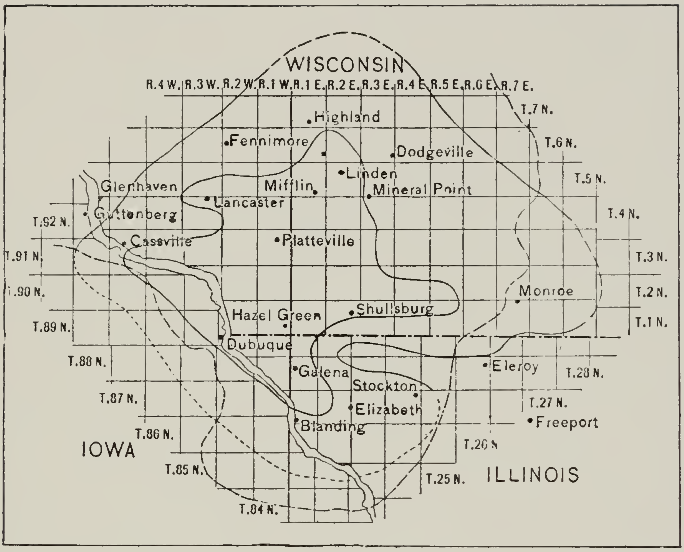


FIG. 60. Map showing distribution of the oil rock in Jo Daviess County and an adjoining area in Iowa and Wisconsin.

Table 48.—*Analysis of gas from oil-rock of Dugdale prospect*

Hydrocarbon vapors	11.11
Heavy hydrocarbons	4.00
CH_4	35.98
H_2S	6.79
CO_2	18.12
CO	8.40
O	.26
H_2	13.18
N_2	2.21
	100.05

"Under the term hydrocarbon vapors are here grouped various hydrocarbons which are liquid at ordinary temperature and which are soluble in alcohol. Benzine may be taken as a type. They contain more than six atoms of carbon per molecule. The heavy hydrocarbons are gases, such as ethylene, acetylene, and their analogues.

Results of other analyses are as follows:

Table 49.—*Analyses of oil-rock*[1]

	Capitola mine	Big Jack mine
Moisture	5.75	8.10
Volatile	22.08	18.65
Fixed carbon	4.23	3.41
Ash	67.93	69.84
Total	100.00	100.00
Sulphur	1.92	1.94
Calories	10.20	9.62
British thermal units	1836	1732

"The following are the results of a destructive distillation test on the sample of oil-rock received April 28, 1909, from Platteville, Wis. The rock as received was crushed to buckwheat size, 500 grams (1.11 lbs.), placed in an iron retort and heated in a furnace previously brought to 1080°C., until practically all the gas was evolved.

"Gas yield, cubic feet per ton at 0°C and 30 in. mercury pressure and dry: 6130 cu. ft.

Table 50.—*Composition of average gas collected from distillation of Platteville, Wisconsin, oil-rock*

CO_2 and H_2S	35.4
Illuminants	2.2
O	1.3
CO	43.6
CH_4, etc.[2]	3.0
H	7.5
N	7.0
	100.00

"The large amount of CO_2 in the gas is to be explained as resulting from the decomposition of calcite or other carbonates in the rock. Probably the CO is in some degree formed by the reduction of CO_2. There is a considerable amount of hydrogen sulphide in the gas as shown by lead acetate paper. The gas burns freely with a colorless flame. The solid residue from the distillation is gray-black in color and can be readily powdered. A certain amount of dark, thin oil was driven over in the test along with water.

"The same sample was subjected to extraction with benzol to remove all naturally occurring petroleum oils, paraffines and asphaltums.

"A second sample was subjected to distillation under atmospheric pressure, and a third sample distilled under a vacuum of 12 mm., with no appreciable increase in yield of oil of the vacuum distillation over the distilla-

[1]Furnished by the U. S. Bureau of Mines, through David White.
[2]Includes all hydrocarbons of C_nH_{2n+2} type.
(N in this gas = 1.93.)

tion under normal pressure, showing that but a small quantity of matter was present as a true oil.

"The total distillate of oil came over between 325°C., and 425°C., both under normal pressure and under 12 mm. vacuum, accompanied with much yellow-brown fog due to decomposition, showing again that there was no appreciable quantity of naturally occurring oil present."

Table 51.—*Quantitative results of distillation of Platteville oil-rock*

Natural oil by extraction with benzol	0.36
Oil of destructive distillation, closely resembling creosotic oils formed by destructive distillation of woods	2.86
Loss due to destructive distillation of vapors and gases of destructive distillation	1.91
Water	8.71
Mineral residue, black and friable, containing a small amount of carbonaceous matter	6.16
	100.00

The statement is made that the oil-rock tested would probably yield not more than 3.22 per cent of oil, and it is suggested that on account of the large amount of mineral matter present, the shale would serve better as a gas- than as an oil-producing material.

Origin of the Oil-Rock

The results of microscopic examination of thin sections of the oil-rock by Mr. David White are given in detail in Bulletin 21,[1] but for the purposes of this report, the material there presented in full is here summarized.

Over 90 per cent of the rock mass is made up of flattened oval or discoid translucent bodies that are distinguishable only under the highest-powered microscopic lenses. They are brilliant lemon-yellow in color and are highly refractive, the birefringence as determined by F. E. Wright being 1.619. These bodies are less than 250/1,000,000 of an inch in their greatest dimension. They are interpreted as the fossil remains of microscopic algae comparable to the living family *Protococcales*. The oil and gas content of the oil-rock is believed to be due either directly or indirectly to these fossilized residues. These algae settled in quiet or protected areas under conditions favorable to the early cessation of anaerobic bacterial decomposition, and subsequent slow changes brought the original plant material to its present state.

To similar fossil remains subjected to similar changes all deposits of oil shales and cannel coals are apparently due.

[1]Op. cit., pp. 28-29.

FULTON COUNTY

A former utilization of a bed of cannel coal is described in the old Geological Survey of Illinois:[1]

"A thin seam of cannel coal occurs in the vicinity of Avon in the northwest corner of the county, and before the discovery of the vast deposits of oil in Pennsylvania, was mined for the distillation of oil. We first visited the locality in 1859, and found ten retorts in operation at that time, the product of which was said to be from three to five hundred gallons of oil per day. The seam from which the material was supplied, was only from fourteen to twenty inches in thickness, and the cost of mining at that time was about two dollars per ton. It was said to yield about thirty gallons of oil per ton but the subsequent discovery of oil in Pennsylvania and Ohio, put a stop to its manufacture from cannel coal in this region."

Professor T. E. Savage has visited the site of the former operations, in sec. 18, T. 8 N., R. 1 E., about a mile north of Avon, and reports that the bed is about 14 inches thick and resembles cannel coal. He identifies it as a coal which commonly underlies the Rock Island (No. 1 coal) a few feet, and is separated from it by a sandstone. This identification fixes the deposits as of Pennsylvanian, more specifically, Pottsville age.

SCHUYLER COUNTY

Source and Description of Samples

Five samples of shale from Schuyler County were tested by Doctor Westhafer of the Department of Chemistry of the University of Illinois in connection with the preparation of a thesis. The results of these tests are here published by permission of that department.[2] The samples, all furnished to Doctor Westhafer by the State Geological Survey, were collected by E. A. Holbrook. Descriptions of the samples are as follows:

Sample No. 1. From the SW. ¼ sec. 12, T. 1 N., R. 1 W. The sample represents 3 feet of paper shale that directly overlies No. 2 coal. The shale has concretions the diameters of which are not uncommonly 1½ by 3 feet. At the top it is fine grained and tough, and at the bottom fissile.

Sample No. 2. From the SW. ¼ sec. 23, T. 2 N., R. 1 W. The outcrop which the sample represents is a 2-foot bed of black, somewhat decomposed calcareous shale containing fossils and concretions. Its stratigraphic position is not definitely known, but it is believed to lie above the horizon of No. 5 coal.

Sample No. 3. From the SW. ¼ sec. 23, T. 2 N., R. 1 W. It consists of concretions taken from the same shale as Sample No. 2. The concretions are hard, tough, and have uneven fracture.

Sample No. 4. From the NW. ¼ sec. 31, T. 1 N., R. 1 E. This sample was taken from 4 feet of blue shale just above No. 2 coal.

[1]Worthen, A. H., Geology of Fulton County: Geological Survey of Illinois Vol. IV, pp. 105-106, 1870.

[2]Abstracted from a Doctor's thesis prepared by T. O. Westhafer during his appointment as Research Graduate Assistant in the Engineering Experiment Station of the University of Illinois, under the general direction of S. W. Parr, Professor of Industrial Chemistry.

Sample No. 5. From the NW. ¼ sec. 31, T. 1 N., R. 1 E. This sample represents a 6-foot bed of black, fissile, carbonaceous shale, overlying 15 feet of blue clay shale, below which is the shale sampled as No. 4.

The shales sampled all belong to the Pennsylvanian system and are of Carbondale age.

Results of Tests

Table 52 gives the results of preliminary tests made on the samples.

TABLE 52.—*Results of preliminary analysis and distillation tests on Schuyler County shales*

	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5
Moisture	1.75	3.95	0.72	0.53	1.67
Volatile	21.15	21.00	39.13	7.02	9.33
Ash	63.80	74.95	51.60	93.40	88.11
Fixed Carbon	13.30	....	8.55	....	0.90
Yield of tar per ton *gals.*	14.7	0.5	0.7	....	....
Bitumen extracted by benzine.....*per cent*	0.67	0.19	0.19	....	....
Total nitrogen *per cent*	0.97	0.39	0.37	0.18	0.36

Only in Sample No. 1 was sufficient organic material present to make further tests worth while. Experimental distillation of this sample gave the following results.

TABLE 53.—*Distillation products of oil shale from SW. ¼ Sec. 12, T. 1 N., R. 1 W. Schuyler County*

Calculated for one ton of shale

Gallons of crude tar at 25° Centigrade	11.7
Cubic feet of gas (n. t. p.)	3100
B. t. u. of gas	690
Gallons of light oil from gas	0.62
Fusion point of ash, in degrees Centigrade	1090

SANGAMON COUNTY

Source and Description of Sample

A sample of black shale included in the Carbondale portion of the Pennsylvanian rocks of Sangamon County has been collected and tested by a representative of the U. S. Geological Survey.

Quoting from Bulletin 641 of the U. S. Geological Survey:[1]

> Sample 9 was obtained from the black shale roof of No. 5 coal at the East Capitol mine in Springfield, Illinois, by breaking up a number of large blocks of black shale that had been removed from the mine about a week before in cleaning up a roof fall. Only the hearts of the blocks were taken to avoid including any shale that might have been weathered along the joints after the removal of the coal. The breaking down

[1]Ashley, George H., Oil resources of black shales of the eastern United States: U. S. Geol. Survey Bull. 641 L, pp. 314 and 319, 1917.

of the shale would naturally follow the joints, and the joint faces would form the outside surfaces of the blocks. The shale appeared to be massive, non-fissile, and blackish drab.

Results of Tests

A preliminary test by David T. Day indicated a yield of 12 gallons of oil per short ton. The results of a more detailed test also by Doctor Day are as follows:

Table 54.—*Distillation products of a Sangamon County shale*
Calculated for one ton of shale

Gallons of oil per short ton	11.9
Gallons of water	9.8
Cubic feet of gas	2,186
Pounds of ammonia	.65

MOULTRIE COUNTY

Source and Description of Sample

A single sample from Moultrie County was tested by Doctor Westhafer. It represents a Pennsylvanian shale which occurs as the "roof-slate" in the Lovington Coal Company's mine. The coal mined is No. 6, and as this bed marks the top of the Carbondale formation, the overlying shale is of McLeansboro age. It is black, hard, and heavy, has uneven fracture, and contains pyrites.

Results of Tests

The results of preliminary tests on this shale and of further tests made in view of the excellent showing in the preliminary work are summarized below.[1]

Table 55.—*Results of preliminary analysis and distillation tests of Lovington roof shale*

Moisture	*per cent*	1.42
Volatile	*per cent*	17.97
Ash	*per cent*	58.65
Fixed carbon	*per cent*	21.96
Yield of tar per ton of shale	*gallons*	16.4
Bitumen extracted by benzine	*per cent*	.60
Total nitrogen	*per cent*	.83

Table 56.—*Distillation products of Lovington roof shale*
Calculated for one ton of shale

Gallons of crude tar at 25° Centigrade	13.7
Cubic feet of gas (n.t.p.)	3285
B.t.u. of gas	640
Gallons of light oil from gas	.57
Fusion point of ash, in degrees Centigrade	1160
Sulphur, per cent	6.62

[1]Abstracted from a doctor's thesis prepared by T. O. Westhafer during his appointment as Research Graduate Assistant in the Engineering Experiment Station of the University of Illinois, under the general direction of S. W. Parr, Professor of Industrial Chemistry.

GALLATIN COUNTY

Source and Description of Sample[1]

A sample of the roof shales of No. 5 coal at the Saline County Coal Company's mine located near the town of Saline Mines was cut by Wallace Lee. Its position with respect to No. 5 coal shows it to belong in the Carbondale formation of the Pennsylvanian system.

Results of Tests

A preliminary test, made by D. E. Winchester, indicated a yield of 12 gallons of oil per short ton, and further tests also by Mr. Winchester, gave the following information:

Table 57.—*Distillation products of a Gallatin County shale*

Calculated for one ton of shale

Gallons of oil	16
Gallons of water	7.5
Cubic feet of gas	Not det.
Pounds of ammonia	3.44

HARDIN COUNTY

A sample of black shale collected by Charles Butts on Hicks Branch, southwest of Hicks, from the top of the Chattanooga shale (Devonian) was tested by D. E. Winchester.[2] As it yielded only a trace of oil and 4.98 pounds of ammonium sulphate per ton, it is not to be classed as an oil shale.

UNION COUNTY

Introduction

Location and Topography

The Union County black shale which has been tested for oil comes to the surface in a belt 75 to 200 feet wide along the west slope of the north-south ridge about a mile west of Jonesboro, as described by Frank Krey.[3] The crest of the ridge is from 150 to 225 feet above the level of the creek flats and the black shale lies generally only 40 feet below the crest. At the gaps of the ridge, however, the easterly dip of the rock brings it to the creek level, commonly within a quarter of a mile east of the crest. The eastern slope of the ridge is gentle, but the western slope is abrupt, especially in its upper portion where vertical faces are not uncommon.

---

[1]Ashley, George H., Oil resources of black shales of the eastern United States: U. S. Geol. Survey Bull. 641 L, pp. 314 and 319, 1917.

[2]Winchester, Dean E., Results of dry distillation of miscellaneous shale samples: U. S. Geol. Survey Bull. 691 B, p. 52, 1918.

[3]Krey, Frank, Geology, distribution, and occurrence [of the potash shale] in Union County: Univ. of Ill. Ag. Exp. Station Bull. 232, pp. 237-243, 1921.

STRATIGRAPHIC RELATIONS

A section of the overlying and underlying strata is as follows:[1]

Section of the Union County black shale and associated strata

		Feet
Quaternary and Cretaceous—		
Loess, gravel, and iron conglomerate		0—40
Mississippian—		
Cherty rock, probably representing the base of the Burlington formation		2—30
Devonian—		
Shale, green (Springville shale)		30—60
Shale, black, carbonaceous and potash-bearing; the "oil-shale" (Mountain Glen shale)		35—45
Limestone, brown, fine grained siliceous and cherty	Alto formation	20—25
Shale, brown, thin bedded, and siliceous		30+

The Mountain Glen shale is probably to be correlated with the Chattanooga shale of Tennessee and the New Albany shale of New York.

Character and Distribution of the Shale

The shale disintegrates rapidly on exposure, but when fresh is hard, black, and thinly laminated, which gives it the appearance of slate. Near the base pyrite is common. Weathering causes the shale to split into thin sheets which are lighter in color than the fresh material and are stained red by iron. Like the other rocks of the section, the shale dips eastward at an angle of 15 degrees on the average.

The constitution of the shale is complex:—free oil, bituminous matter, pyrite, undecomposed potassium-bearing mineral, probably felspathic in character, and potassium-bearing mineral of a glauconitic character.[2]

The outcrop of the shale which, as previously stated, lies high on the west slope of the ridge a mile west of Jonesboro, marks the western limit of the shale. To the north the outcrop is terminated by a northwest-southeast fault in sec. 22, T. 11 S., R. 2 W., northwest of Mountain Glen. And its southern end lies in the southern part of Sec. 23, T. 12 S., R. 2 W. Its extent eastward from the line of outcrop is unknown because its horizon is concealed by an increasing thickness of younger strata, but the probability is that it is at least several miles.

SOURCE OF SAMPLES

Four samples of shale from Union County were collected by E. A. Holbrook of the State Geological Survey, and the results of tests made on them by Doctor Westhafer are published with the permission of the Department of Chemistry.[3]

[1]Parr, S. W., and Austin, M. M., Potash shales of Illinois: Univ. of Ill. Ag. Exp. Station Bull. 232, p. 238, 1921.
[2]Ibid., p. 236.
[3]Abstracted from a doctor's thesis prepared by T. O. Westhafer during his appointment as Research Graduate Assistant in the Engineering Experiment Station of the University of Illinois, under the general direction of S. W. Parr, Professor of Industrial Chemistry.

Sample 1. From SE ¼ sec. 1, T. 13 S., R. 2 W., about 3 miles south of Jonesboro. This sample represents two bands of chocolate-colored shale about 16 to 18 inches thick and 18 feet apart, both of which lie in an exposed bank of many feet of tough, fissile, gray and green shale (the Springville shale). The beds sampled are hard and flinty and have an uneven fracture.

Sample 2. From SW. ¼ sec. 11, T. 12 S., R. 2 W., about 3 miles northwest of Jonesboro, on Caney Creek. This sample was taken from the lower 10 feet of a 35-foot bed of chocolate-colored and black fissile shale (the Mountain Glen shale).

Sample 3. From the same location as Sample 2, but taken from the upper 25 feet of the bed.

Sample 4. From SW. ¼ sec. 9, T. 2 S., R. 1 W., about 2 miles north of Anna. A fossiliferous brownish shale bed, 15 feet thick was the source of this sample. Its age is not definitely known.

Results of Tests

Table 58 gives the results of preliminary tests made on these four samples.

Table 58.—*Results of preliminary analysis and distillation tests on four Union County shales*

Calculated for one ton of shale

	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
Moisture . . . *per cent*	1.30	1.01	1.25	3.25
Volatile . . . *per cent*	10.50	10.29	11.60	9.82
Ash . . . *per cent*	92.55	87.40	85.51	89.20
Fixed carbon . . . *per cent*	. . . . . .	1.30	1.64	. . . . . .
Yield of tar per ton . . . *gals.*	. . . . . .	4.5	4.2	. . . . . .
Bitumen extracted by benzine *per cent*	. . . . . .	0.15	0.20	. . . . . .
Total nitrogen . . . *per cent*	0.13	0.41	0.51	0.04

Samples 1 and 2 contained only very small amounts of carbonaceous material, but the content of samples 3 and 4 was such as to encourage further tests, the results of which follow.

Table 59.—*Yield of gas and tar from two Union County shales*

Calculated for one ton of shale

	Sample 3	Sample 4
Gallons of crude tar at 25° Centigrade . . .	2.0	1.9
Cubic feet of gas (n.t.p.) . . .	1208	2200
B.t.u. of gas . . .	600	510

JOHNSON COUNTY

Introduction

The results of exhaustive tests by Dr. T. O. Westhafer of samples of an oil shale taken by a Survey representative from near Ozark are here

published, amplified by geological material taken from the field notes of Dr. G. H. Cady and Professor E. A. Holbrook, and from published reports. This deposit is particularly interesting because of its commercial possibilities.

The kindness of Mr. Frank Stone of Ozark and especially the helpful interest and assistance of Dr. J. E. Blanchard, extended to members of the Survey during their brief inspection trips to the deposit, are gratefully acknowledged.

LOCATION AND TOPOGRAPHY

The Ozark oil-shale deposit lies chiefly in secs. 27, 34, and 35, T. 11 S., R. 4 E. (Burnside Tp.), about two miles southeast of the Illinois Central Railroad station of Ozark, and within a mile east of the railroad track as it passes south from Ozark. Hilly, rugged topography characterizes the area. The divides between creeks and their tributaries are conspicuous ridges, and their high points lie commonly 50 to 100 feet above the hollows.

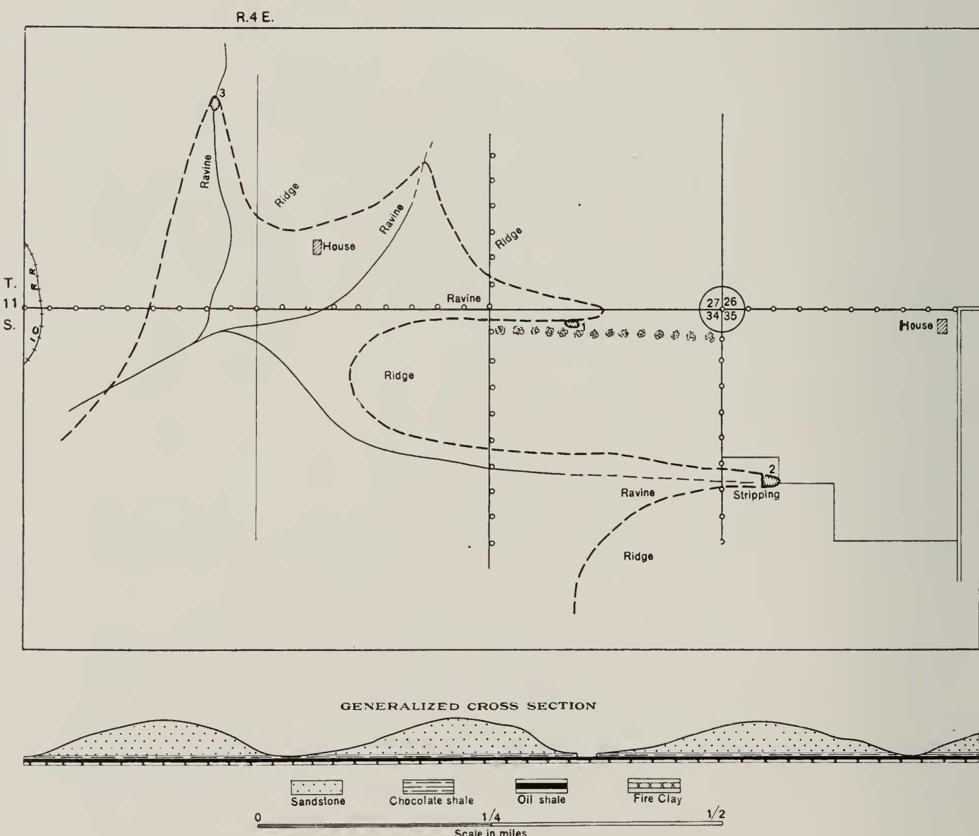


FIG. 61. Sketch map based on work of G. H. Cady, showing the oil shale outcrop near Ozark in Johnson County.

Figure 61 outlines the deposit, and by means of a diagrammatic section indicates the relation of the ridges and hollows to the shale and the strata overlying and beneath it.

STRATIGRAPHIC RELATIONS

The rock outcropping on the tops and upper slopes of the divides is resistant yellow sandstone, and the boulders in the fields on their lower slopes are also of hard yellow and red streaked sandstone. Underlying this sandstone and separating it from the oil shale is a 6- to 8-foot bed of dark chocolate-colored shale; and beneath the oil shale is at least 5 or 6 feet of "clean" white fire clay. These relations are indicated diagrammatically in the section in figure 61.

These strata belong to the Pennsylvanian system and are all of Pottsville age. In this part of the State the Pottsville strata consist of alternating sandstones and shales as shown in the following generalized section.[1]

Generalized section of Pottsville strata

	Thickness *Feet*
Shales with thin beds of sandstone and sandy, micaceous shale; local limestones and coal beds; some gypsiferous shale	400
Upper cliff-making sandstone, massive, cross-bedded sandstones not conglomeratic, commonly ironstained	100–200
Shale with thin sandy layers and local coal beds	75–125
Middle cliff-making sandstone, massive, quartzose sandstone with local conglomeratic lenses	40–150
Shale with thin micaceous sandy beds and local dirty coals	40– 60
Lower cliff-making sandstone, massive cross-bedded sandstone with conglomeratic beds	100–250
Brown gritty shale	10– 40

As will be noted from the above section, the oil shale is a part of the shale horizon that separates the upper and lower cliff-making sandstones.

The Oil Shale

DESCRIPTION

The deposit is exposed commonly in the hollows as a 2½- to 3½-foot bed of black laminated shale on the face of which scattered white oily blotches appear. Its distinct tendency to split along the bedding planes in thin sheets gives it somewhat the appearance of a hard, firm, black slate. The term "cannel coal" has been applied to the bed, but the laminations are so numerous and conspicuous that "carbonaceous oil shale" is a much better descriptive term. Extending back from the face in two directions at right angles to each other are incipient, approximately vertical, cleavage planes which are wavy and sinuous rather than in sharp straight lines. When the shale is mined, it tends to split along these planes into large, roughly rec-

[1]Brokaw, A. D., Parts of Saline, Johnson, Pope, Williamson counties: Ill. State Geol. Survey Bull. 35, p. 24, 1917.

tangular blocks commonly about 1 foot thick, 20 inches long, and perhaps 12 inches wide.

The 5-foot bed of carbonaceous shale which immediately overlies the oil shale is siliceous, and under the ridges it is covered by thick hard sandstone which would probably make a good roof for mining.

The following section was measured in a test pit near the stripping operations on the Frank Stone land.

Section of oil shale measured in a test pit on the Frank Stone land in the NW. ¼ NW. ¼ sec. 35, T. 11 S., R. 4 E.

	Thickness *Ft.*	*In.*
8. Soil, yellow	1 to 5	..
7. Shale, chocolate siliceous	4	2
6. Mud, red, merely a streak	..	..
5. Oil shale	2	9
4. Coal, bituminous	..	1½
3. Coal, cannel	..	4
2. Coal, bituminous, with peacock-colored blotches	..	2
1. Fire clay, white	5+	..

Fig. 62. Photograph of the outcrop of the Ozark oil shale and the overlying cholocate-colored shale, in the SW. ¼ NW. ¼ NW. ¼ sec. 35, T. 11 S., R., 4E., Johnson County.

DISTRIBUTION

At the stripping operations in the creek bed, on the Stone land in the SW. ¼ NW. ¼ NW. ¼ sec. 35, is perhaps the best typical exposure of the oil shale (fig. 62). As mined it is 31 to 32 inches thick, though in the nearby test pit from which the samples were taken for testing and in which the preceding section was measured, its thickness was about 8 inches greater.

In the hollow immediately north of the stripping operations, in the woods along the north line of the NE. ¼ NE. ¼ sec. 34, there are several old pits that are now partly filled so that the shale is no longer exposed. It is said to lie from 5 to 20 feet below the surface.

In the creek bed in the NE. cor. SE. ¼ SW. ¼ sec. 27, the shale is not well exposed, but it is apparently less than 30 inches thick.

Fragments of the shale were found at a pit west of the Illinois Central Railroad about half a mile south of the north line of sec. 34, but the thickness of the bed at this point could not be determined because the pit was covered.

Fragments of the shale were also found in the bed of a creek in the NW. ¼ NE. ¼ sec. 35, about half a mile northeast of the test pit on the Stone land; but none was found in the next ravine half a mile farther east in the west half of sec. 36.

In an old well about a quarter of a mile southeast of the Stone pit, the shale is reported at a depth of 22 feet, which is at practically the same elevation as it is in the pit.

All these outcrops are shown on the sketch map (fig. 61) and the approximate boundary of the shale at intervening points is indicated. Apparently the shale seems to be present under nearly all but the SE. ¼ sec. 35; only in NE. ¼ sec. 34; and all but a small area in the S. ½ SE. ¼ sec. 27. West of sec. 35 it is not definitely known to be present, at least in workable thickness, and in the east part of secs. 26 and 35 it is possibly too thin to work. The continuity of the bed northward is practically undetermined. The available data indicate that the best shale underlies sec. 35 and it may extend under at least part of sec. 36.

PRESENT USE

The farmers in the vicinity use the shale in their cookstoves and fireplaces. For their cookstoves they pound up the lumps with the head of an axe until they are reduced to flat pieces 2 to 3 inches square. The noise and results of the operation resemble what would take place if one struck a pile of roofing slate with an axe. For the open fireplaces, the large lumps are rolled in and burn freely with a very long hot flame. They split horizontally when heated and when one is pried apart often it reveals a little pool of oil which has "stewed" out of the shale and collected in the hollows. As this is exposed to the air it burns with a long flame and a noise resembling hot fat when dropped on a hot stove. After the oil burns out of the shale, the ashes commonly retain their original shale form but have become soft and gray.

SOURCE AND DESCRIPTION OF SAMPLES

Sample 1. From NW. ¼ sec. 35, T. 11 S., R. 4 E. A 42-inch thickness of the shale was sampled.

Sample 2. Represents the same shale as does Sample 1, but was taken from a 20-ton pile of the shale mined and dumped beside the outcrop. It was somewhat mixed with leaner material.

Sample 3. Represents the 50-inch chocolate shale lying above the deposit where Sample 1 was taken.

Sample 4. From a shaft sunk about a quarter of a mile from the outcrop from which Samples 1 and 2 were taken. The sample consisted of a 1500-pound shipment of freshly mined shale. It was slightly heavier and less weathered than Samples 1 and 2.

Results of Tests

Samples of the oil shale were tested by Dr. T. O. Westhafer of the Department of Chemistry of the University of Illinois in the winter of 1917-1918. On the following pages will be found some of the results of these tests, abstracted from a doctor's thesis prepared during Mr. Westhafer's appointment as Research Graduate Assistant in the Engineering Experiment station of the University of Illinois, under the general direction of S. W. Parr, Professor of Industrial Chemistry. Table 60 is based on preliminary tests.

Table 60.—*Results of preliminary analysis and distillation tests on four Johnson County shales*

	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
Moisture................. *per cent*	1.77	1.96	1.80	1.65
Volatile.................. *per cent*	33.73	31.69	8.75	36.80
Ash...................... *per cent*	38.50	42.85	88.35	38.45
Fixed carbon............. *per cent*	26.00	23.50	1.60	23.10
Yield of tar per ton.......... *gals.*	38.4	36.0	....	48.8
Bitumen extracted by benzine .... *per cent*	1.09	0.98	....	1.16
Total nitrogen............ *per cent*	0.89	0.82	0.35	0.92

The fact that only about 1 per cent is extracted by solvent benzine shows that free oily or asphaltic matter exists in only very small amounts and that therefore distillation is the only possible method of obtaining their content of bitumen. In this connection it is to be noted that Colorado and Utah shales yield about 6 per cent of their weight when treated with either benzine or ether.[1]

[1]Woodruff, E. G., and Day, D. T., Oil shale of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 581 a, 1915.

Further tests on samples 1 and 4 are summarized in Table 61.

TABLE 61.—*Yield of oil and by-products from the Ozark shale of Johnson County*

Calculated for one ton of shale

	Sample 1	Sample 4
Gallons of crude tar at 25° Centigrade	36.6	45.1
Cubic feet of gas (n.t.p.)	6389	5860
B.t.u. of gas	690	760
Gallons of light oil from gas	2.44	2.28
Fusion point of ash, in degrees Centigrade	1240	1240
Sulphur, per cent	....	1.18

The results of the analysis of the tar obtained from these two samples are given in Table 62; of analysis of the gases, in Table 63; and of analysis of the light oils from the gas, in Table 64.

TABLE 62.—*Results of analysis of tar obtained from two samples of Ozark shale from Johnson County*

Cut	Sp. Gr. at 25° C.	Per cent paraffin	Per cent unsaturated hydro-carbons	Per cent aromatic hydro-carbons	Acids	Bases
			Sample 1			
To 150° C.	.770	54	34	10	..	2
150-225°	.823	44	37	6	8	5
225-300°	.865	42	38	11	5	4
Over 300°	.926	..	46	..	..	..
Crude tar	.897	..	55	..	..	..
			Sample 4			
To 150° C.	.776	59	27	12	..	2
150-225°	.828	48	31	9	6	6
225-300°	.871	35	50	8	4	3
Over 300°	.930	..	65	..	..	..
Crude tar	.901	..	72	..	..	..

TABLE 63.—*Results of analysis of gases from two samples of Ozark shale from Johnson County*

	Sample 1	Sample 4
Carbon dioxide	6.7	5.0
Oxygen	0.3	0.3
Acetylene	0.0	0.1
Unsaturated hydrocarbons	4.4	6.0
Ethylene	1.2	1.3
Aromatic hydrocarbons	1.0	1.3
Hydrogen	34.9	29.4
Carbon monoxide	2.3	3.0
Methane	23.1	25.1
Ethane	21.9	24.5
Nitrogen and residue	2.2	3.0
B.t.u.	690	760

TABLE 64.—*Results of analysis of light oils from two samples of Ozark shale from Johnson County*

Fraction	Per cent weight	Sp. Gr. at 25° C.	Per cent paraffin hydrocarbons	Per cent unsaturated hydrocarbons	Per cent aromatic hydrocarbons
SAMPLE 1					
To 95° C.	52.2	0.719	67	27	6
95-125° C.	35.5	0.733	64	27	9
125-133° C.	3.5	0.738	75	22	3
SAMPLE 4					
To 95° C.	40.5	0.721	72	22	7
95-125° C.	44.3	0.728	70	24	6
125-133° C.	6.7	0.742	..	..	..

INDEX

3 plates